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Malaysian Parasites

I—XV

Institute for Medical Research

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MALAYSIAN PARASITES, I-XV





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INSTITUTE FOR MEDICAL RESEARCH
FEDERATION OF MALAYA
No. 26

MALAYSIAN PARASITES

I—XV

EDITED BY J. R. AUDY
Division of Virus Research and Medical Zoology

1953
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PREFACE

The present *Study* from the Institute for Medical Research, Federation of Malaya, is intended to be the first of a series which will gather together information relating to various groups of external and internal parasites of man and animals in the Malaysian region. Instead of being scattered among different journals, descriptions of the extensive collections and investigations made in Malaya will thus be available in one series of publications.

Experience has repeatedly shown that every attempt to advance our understanding of the arthropod-borne endemic infections has exposed a considerable and lamentable lack of knowledge of local species of potential vectors and their relationships with animal hosts. It is therefore important to investigate the ectoparasites on a broad basis, without being too rigidly directed by knowledge or suspicion of the ability to transmit disease. Many of the parasites described are already known to transmit infections, or themselves to cause disease, among their animal hosts ; and a number affect man secondarily.

The material drawn upon is largely that collected by the Colonial Office (Scrub Typhus) Research Unit, which was supported by Colonial Development and Welfare funds until 1952, since when the research has been equally supported by the Colonial Office and the Government of the Federation of Malaya. In mid-1953, the Colonial Office Research Unit was formed into a new Division of the Institute—the Division of Virus Research and Medical Zoology.

A general account of the collections is given in the first paper of this series. The study of certain groups of parasites has been taken over by various authorities in collaboration. Particular mention should be made of Robert Traub and his colleagues, who are studying the fleas, lice, and acarine parasites ; Edward W. Baker, collaborating over parasitoid mites ; A. A. Sandosham, who is studying helminths ; and Glen M. Kohls, who is studying the ticks. The Colonial Office Unit itself has confined its purely taxonomic studies to the trombiculid mites (J. R. Audy) and the animal hosts (J. L. Harrison). A great deal of support has been given for investigations in Borneo and Malaya by the Research and Development Board, Office of the Surgeon-General, U.S. Army. Special acknowledgment must be made of the generous support and collaboration of Joseph E. Smadel and his colleagues, of the Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington.

J. W. Field
DIRECTOR

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MALAYSIAN PARASITES I

COLLECTIONS MADE IN MALAYA BY THE COLONIAL OFFICE SCRUB TYPHUS RESEARCH UNIT*

By

J. R. AUDY AND J. L. HARRISON

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INTRODUCTION

The formation and purpose of the Colonial Office Scrub Typhus Research Unit at the Institute for Medical Research have already been described (Audy & Harrison 1951). An account of the rodents and insectivores collected during 1948 has also been published, in collaboration with the U.S. Army Research Unit in Malaya (Harrison & Traub 1950). A provisional tabulation of animals and some of their trombiculid parasites was published in the Annual Report of the Institute for 1949 (Table 31, pp. 99-101). The present paper brings up to-date the lists of hosts which have been collected and studied in Malaya, while it also adds details of infestation by various species or groups of trombiculid mites and gives an account of the collecting areas and the method of collecting and recording specimens. Gross infestation data are given of external parasites other than the trombiculids.

Between the beginning of 1948 and the end of 1952, a total of 21,151 vertebrates (and a number of invertebrates known to be infested by trombiculids) were collected and examined in Malaya. A very large number of parasites from these hosts have been collected but only the trombiculids have yet been worked out in any detail. Other collections have been made,

* Now included in the Division of Virus Research and Medical Zoology, Institute for Medical Research.

mostly in collaboration with other workers, but these are not considered in detail in the present paper: several collections are briefly described below. The bulk of the routine animal collection is made up of rodents and insectivores, rodents contributing about 85 per cent. and insectivores a little over 5 per cent. The collection represents some 115 species of mammals, about 30 species of birds, and about 90 species of reptiles and amphibians.

In addition to the above routine collection, parasites are collected from "mark-release" experiments (*see below*) and also trombiculids from the ears of rats (totalling some 2800 pairs) which were regularly sent from Singapore and Klang during 1948-1951. A similar collection from the ears of 40 rats was also sent from Hong Kong (1949-1950) by Mr J. D. Romer. Nymphal and adult stages are also collected in the field. The parasites are generally mounted in a polyvinyl alcohol medium (PVA), the recognisable species identified, and series set aside for study. Many photographs of animals, photomicrographs of mites, and drawings have been made.

A valuable collection of trombiculid mites and a few mammal hosts from various parts of India has been sent by Lt-Colonel S. Lal Kalra, formerly Pathologist in charge of the G.H.Q. (India) Field Typhus Research Detachment attached to the joint laboratory at Imphal, and now at the Armed Services Medical College, Poona. Most of Kalra's new species of mites have been described by Womersley (1952). Dr. Carl Gibson-Hill of the Raffles Museum, Singapore, made a collection on behalf of the Unit in the Nicobar Islands in 1950. Another valuable collection of over 700 hosts and their parasites was made in Sarawak between May 1950 and January, 1952, in collaboration with Mr. Tom Harrison, Government Ethnologist and Curator of the Sarawak Museum, Kuching, and also with Traub. Two collections from 944 animals were made in North Borneo jointly by the U.S. Army Research Unit (led by Traub) and the Colonial Office Research Unit in 1951 and 1952. A major collection from Thailand was made by Mr. Robert Elbel of the Plague Control Section of the U.S. Special Medical and Economic Mission to Thailand. By the courtesy of our colleague Traub, a part of this collection is being studied jointly. These collections from India, the island of Borneo, and Thailand will be made the subject of other papers by various authors. Some of the findings have been provisionally summarised in a following paper (Audy 1953a, this *Study* p 30).

We particularly wish to record our advantageous association with the several U.S. Army Medical Research Units which have visited Malaya. Directed by Dr. Joseph E. Smadel and, except for the first team, led by Lt-Colonel Robert Traub, these teams have represented the U.S. Army Research and Graduate School at Washington, D.C., and the Commission on Immunisation of the Armed Forces Epidemiological Board. There were four visits of several months each by these research teams between 1948 and 1951. This collaboration is expected to continue. While working at the Institute, Traub and his colleagues have made many collections of hosts and parasites, independently or jointly with the Colonial Office Unit. At all times the exchange of material and information between the two units has been complete and we are greatly indebted to our American colleagues, and in particular to Lt-Colonel Traub and Dr. Smadel, for their many courtesies and their hearty collaboration.

A GENERAL ACCOUNT OF THE COUNTRY

Malaya lies between 1° and 7° north of the equator and contains mountains up to 2,000m, low hilly terrain, and plains in roughly equal proportions. It appears originally to have been covered entirely by Tropical Rain Forest in which from very early times the aboriginal pigmy tribes have practised shifting cultivation in clearings. Possibly for some thousands of years the major river valleys and coastal areas, especially in the west flank, have been cleared to a limited extent, settled, and devoted to the cultivation of such crops as rice. During the last century, and particularly during the last half-century, large tracts have been cleared of forest and either

the top-soil has been destroyed by opencast tin mining, or the land has been planted with rubber and oil-palm (which simulate forest) and pineapple (which provides very little cover). At present about 75 per cent. of Malaya is still covered with forest, either virgin or secondary. Kuala Lumpur in the State of Selangor lies in an intricate mosaic of vegetation, as may be seen by the following Table (1), derived from recent 1-inch maps, which shows the composition of the mosaic of 1,200 square miles in Selangor, including all our major collecting areas.

TABLE 1
VEGETATION MOSAIC IN SELANGOR
(from Audy 1948)

A. Forest (made up of 34% Dipterocarp Forest, 7% Swamp Forest, and 2% Mangrove)								43 per cent.
Coastal mudbanks								1 „ „
Water (rivers, lakes, and mining pools)								1 „ „
Total virgin country (mostly Forest Reserves)								45 „ „
B. Plantations (nearly all rubber)								35 per cent.
Scrub (1% being clearings in rubber)								12 „ „
Total scrub and plantations								47 „ „
C. Villages, town, squatters and Malay reserves, including domestic waste land, small native gardens, etc..								5-7 per cent.
D. Mining areas, mostly scrub and shallow pools								1-3 „ „

During the Japanese occupation an attempt was made to improve the output of homegrown food by clearing areas of forest or rubber plantation and settling them with market gardeners. Laudable though this idea may have been, it did not succeed too well. Large areas were cleared but never brought under effective cultivation, while other farmsteads were soon abandoned and "squatter" areas in varying stages of neglect appeared. The cleared land was soon overgrown by the intractable tall thatch-grass "lalang" (*Imperata cylindrica*), which takes fire easily and burns with little damage to its rhizomes but with the destruction of any regenerating forest growth. The nett result was to add to the waste-land of Malaya. This was probably largely responsible for the post-war increase in the incidence of scrub typhus : 250 recorded cases in the three years 1939 to 1941, and some 1,020 cases during 1947 to 1949.

The faunæ of these different parts of the vegetation mosaic are illustrated in Table 2, in which are shown all the species of potential mite host which have been examined, with an indication of their occurrence and abundance in different habitats, and of the abundance of the commoner mites upon them. Further details of mite-infestation are given in Table 3.

A GENERAL ACCOUNT OF THE COLLECTIONS

The major collecting areas in Selangor

Trapping for the Colonial Office unit is carried out by estate labour, casual employees, several groups of Aborigines who collect in the forests, and by certain personnel employed by the Kuala Lumpur Municipality. A light van is in constant use for bringing in specimens. Mr. Ben Ensoll, Collector for the Selangor Museum (which was almost completely destroyed

by bombs in 1945) has been shared by the American team and ourselves, by the courtesy of the Director of Museums, to whom we are very grateful. Mr. Ensoll was lent to this Unit in January, 1948, and officially seconded from the Museum in 1950.

The main sources have been : Kuala Lumpur town, an Oil Palm Estate (part of which was the site of the classic outbreak in 1924-1930), various tracts of wasteland, and four forest reserves. These are shown on the maps, Figs. 1 and 2 and in the accompanying photograph. Three areas in Johore, one in Negri Sembilan, several islands in the Straits of Malacca, and one of the Nicobar Islands have been investigated briefly. The findings are noted below.

In more detail, the collecting areas are as follows (*see* the map, Figure 2) :

A. FOREST :

1. *Bukit Lagong Forest Reserve*, by a party of Aborigines living there. Referred to in notes as "Kepong". (*Bukit*=hill).
2. *Bukit Lanjan (Sungei Buloh Forest Reserve)*, by a party of Aborigines living there. A very small reserve much surrounded by young and old secondary growth in which much of the trapping takes place (Fig. 3). (*Sungei*=stream).
3. *Ulu Gombak Forest Reserve: "Pahang Road"*, by a group of Aborigines who lived there wandering over an area traversed by some 20 miles of road. Collecting area mostly Selangor, partly Pahang : occasional collecting from surrounding mountains. Owing to bandit interference this party of Aborigines moved away in November, 1949, to Ulu Langat, and the collecting area was then abandoned. (*Ulu*=upper reaches of a river; upcountry).
4. *Ulu Langat Forest Reserve*, in the next major valley south of Gombak but not so easy to reach from Kuala Lumpur; also by a group of Aborigines. This is the most remote and undisturbed of the forest collecting areas.

B. KUALA LUMPUR TOWN : by town rat-catchers.

C. OIL PALM ESTATE (Elmina) near Sungei Buloh, by estate labour. This was the site of the outbreak described by Fletcher and Field (1927). The formerly infected area, now known as Field 3, is covered in fully grown palms and appears to be no longer dangerous. Fletcher *et al.* (1929) record some mites collected from this field. Records by Gater (1932) of Sungei Buloh as a type locality refer to this estate and the forest immediately adjoining it. It would however be justifiable to accept material collected from what we call the Bukit Lanjan F.R. and the Sungei Buloh Settlement as topotypic with Gater's species.

D. WASTELAND AROUND KUALA LUMPUR :

1. *Subang*
2. *Seaport Estate* at Sungei Way—site of exposure of volunteers in the field trials of chloromycetin in 1948, described by Philip *et al.* (1949).
3. "*West Folly*", an area of scrub bordering on the Lake Gardens.
4. *Casual areas*—Jinjang Estate, Wardieburn Estate, Taynton Estate, Cheras Estate, etc.

E. VILLAGES AROUND KUALA LUMPUR : *Sungei Buloh*, village and leper settlement; *Kepong* village.

F. MARK-RELEASE SCHEMES (*see* below) at Sungei Buloh and in Kuala Lumpur.

G. EARS (with mites attached), sent by post :

1. *Singapore* by Dr. S. Y. Ng, Municipal Laboratory (1312 pairs regularly from May, 1948 to August, 1951).



1. The Malaysian and Indochinese parts of the Oriental Region Current collections have been made outside Malaya in the following places which are shown on the map : Car Nicobar ; Jarak and islands on either side of it in the Malacca Straits ; Kuching ; Mt. Kinabalu and several other sites in North Borneo ; and Hong Kong. Other collections have been made in Bangkok and (during the War) in Rangoon, lower Burma, and the Philippines. Further details of collecting areas are shown in the maps on pages 7 (collecting areas in Selangor), 13 (land-usage in Selangor), and 61 (collecting areas in North Borneo).

2. *Klang and Port Swettenham*, by Dr. M. I. Mohamed, Health Officer, Coast (1072 pairs regularly from January, 1949 to August, 1951).
3. *India* (mostly North India), by Kalra (34 pairs, 1949 to 1952).
4. *Hong Kong*, by Mr. J. D. Romer, Municipal Health Office (40 pairs, 1949 to 1950).
5. *Kuching area, Sarawak*, by Tom Harrison (414 pairs, 1950 to 1952).

Body Service

We have borrowed this term from Mr. Charles Elton, F.R.S. : it implies all the routine processes of collecting, examining, and otherwise dealing with the individual animals which are being investigated.

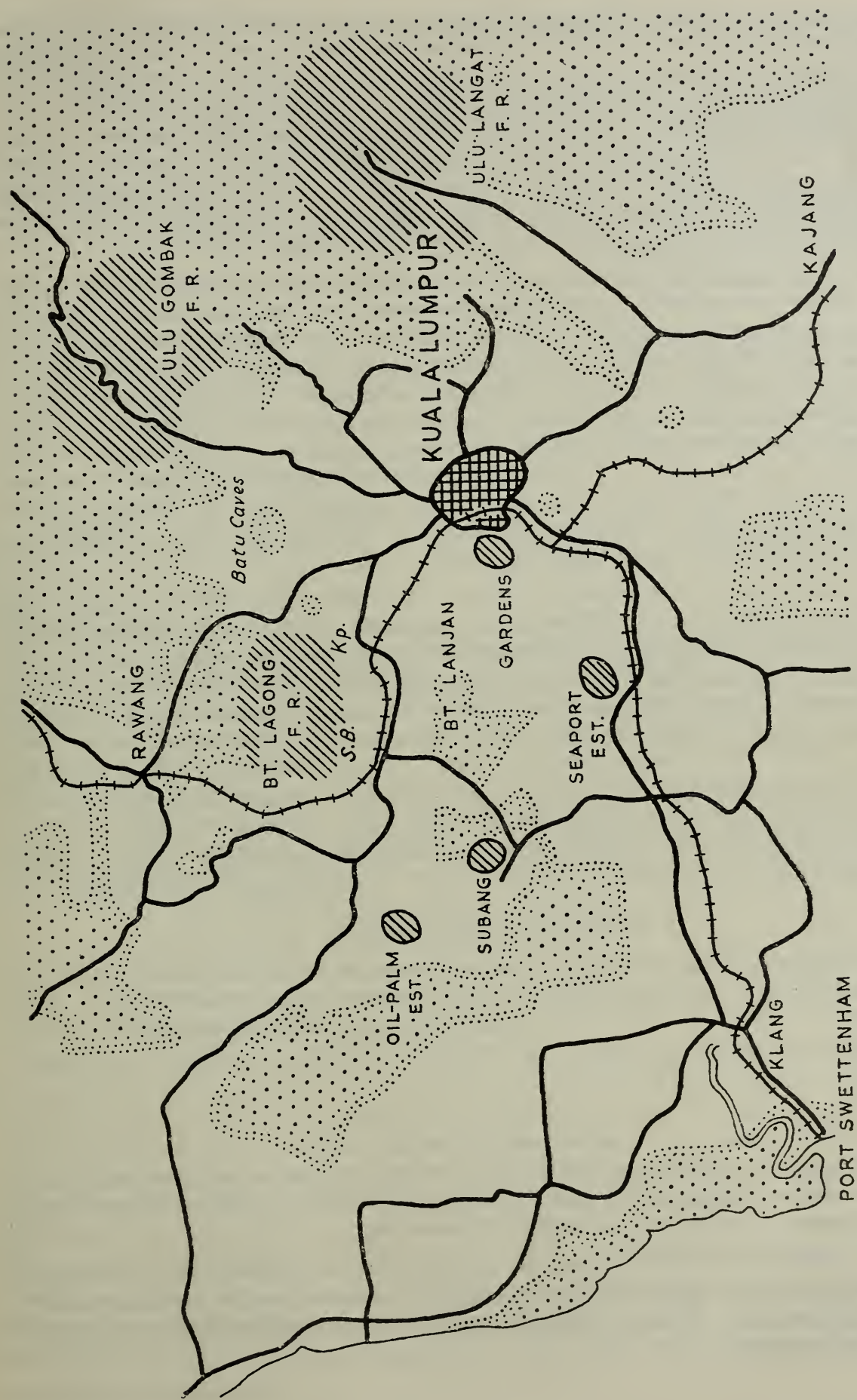
Animals are trapped in wire cage traps of standard pattern, in forest by Aborigines, in Estates by estate labourers, in wasteland and special localities by our own trappers, and in town by the municipality's trappers, usually on a reward basis.

Every vertebrate brought into the laboratory is entered in a register and given a number (prefix R). The date, place, and method of capture are recorded and the species if known. Some animals are retained for observation, others are collected for keeping over water so that engorged larvae may be recovered for breeding (and also so that feeding times may be estimated), but most animals are put into white cloth bags and killed with the petrol-gas which is piped to the laboratory. All visible ectoparasites are then removed and either mounted in PVA or preserved in spirit. Trombiculid mites are searched for and removed under a stereoscopic dissecting microscope ; fleas, lice, parasitoid (gamasoid) mites, and similar parasites are collected by shaking, beating, and combing, but no special techniques are used for the recovery of any of these.

The host body is then measured and weighed, photographed if such records are lacking, examined for fertility (presence of sperm or embryos) and stomach contents, and, if worthwhile, the skin and skull are preserved. Skins are mounted flat on cards by the method devised by Elton (1938). Attempts are being made to build up a collection of photographs of the living animals. A certain number of live animals of various interesting species are regularly kept in the laboratory under observation.

All this information is recorded in the register and thence transferred as required to punch-cards. Admittedly the double entry increases the work involved, but since several laboratory assistants may be involved a register system allows for better control. No body is disposed of until its entry in the register has been initialled by a responsible officer. The senior laboratory assistant responsible for the animals is Mr. Lim Boo-Liat, who is assisted by Mr. Abdul Rahman.

Ectoparasites are either mounted on glass slides or preserved in spirit, frequently in pools relating to particular species of hosts. The trombiculid mites are mounted and identified as a matter of routine but as each host-species from each locality becomes adequately sampled, its parasites are thenceforth pooled and preserved in spirit. Other ectoparasites were formerly mounted on slides but are now pooled by host-locality or by host species. These are passed on to our colleague Traub at intervals. They are being studied by various workers : the parasitoid mites by Dr. Edward W. Baker (U.S. Department of Agriculture) in collaboration with Traub and his colleagues ; the ticks by Dr. Glen M. Kohls of the Rocky Mountain Laboratory ; the fleas by Traub ; and the lice by Dr. Wernicke of Brazil. The trombiculids are being studied by Audy in collaboration with Mr. H. Womersley of the South Australian Museum, Adelaide, and with Traub and his colleague Dr. Douglas Gould of the U.S. Army Medical Service



2. Major Collecting Areas in Selangor.

Deforested land is shown blank. The remaining Forests (dotted) are mostly on hills, except for those east of a line joining Oil Palm Estate, Subang and Kajang, which are swamp-forests or coastal mangrove forest. The major collecting areas are shown by cross-hatching, except for the small patch of forest on Bukit Lanjan. The letters *S.B.* and *Kp.* stand for Sungai Buloh and Kepong.

Graduate School. Between 1948 and 1952 a large number of trombiculids were selected after screening the collections and sent to Mr. Womersley, for whose help we are extremely grateful. He has already described 23 of the new species collected (Womersley 1952). It is intended that most of the remaining new species shall be described by various authors in this present series of papers on Malaysian parasites. The routine identification of trombiculids has been kept fairly well up to date, and more attention is now being paid to breeding different species, correlating larvae with postlarval stages, and making ecological studies. The identification of the other ectoparasites has inevitably lagged behind. It may thus be several years before the identification of the parasite fauna of one particular host is reasonably well worked out.

The hosts examined for parasites are listed on specially printed cards according to time, locality, and host species-group. Against each host is tabulated the numbers and species of all ectoparasites, as they are identified. Each card, therefore, when complete, gives the summary of the ectoparasite fauna of all hosts of a particular group, collected in a particular locality or area, during a specified time. Any host which is brought in dead, when the parasites may have left, is completely ignored for the purpose of these particular records. The senior assistant responsible for the parasite collection is Mr. Nadchatram, ably assisted by Messrs. Lee Fatt-Hing and Johan bin Haji Adam. A separate section devoted to breeding mites and experiments connected therewith was formerly in the charge of our colleague Mr. K. L. Cockings, who left the Unit in August, 1950. A number of colonies of mites are now being maintained by Messrs. Aman bin Mohamed and Harun bin Peral.

The examination for endoparasites was not systematic until November, 1950, when collaboration was established with Professor A. A. Sandosham of the Department of Parasitology, University of Malaya, Singapore. Prof. Sandosham's Department has paid for the employment of an assistant, Mr. Phang Ong-Wah, who is responsible (among other duties) for the collection of endoparasites. A considerable collection of helminths has now been made and a preliminary note on these follows (Sandosham 1953, this *Study*, p. 23). Collaboration has also been established with Prof. R. Hoeppli, who is a visitor to Prof. Sandosham's Department and is studying the histopathology of bites due to arthropods, in continuation of work which he has carried on for many years (Feng and Hoeppli, 1933). Animals of certain groups at certain times are passed to the Malaria Research Division of the Institute for blood examination, and some of the results have been reported by that Division (e.g. Field and Edson, 1949).

Mark-Release experiments

In addition to the routine collections described above, the animals trapped in certain areas are examined, marked, and released again, usually, to be recaptured from time to time. Most of the animals so marked are rats of various species, but toads, monitor-lizards, tortoises, shrews, and squirrels have also been recovered after marking. The rats are marked by a system of toe-clipping.

On capture or recapture the animal is slightly anaesthetised and all visible trombiculids are removed. Other parasites are collected casually, but no systematic search is carried out for them. The animal is weighed and the details of weight, infestation, and place and time of capture and release are entered on a card for each marked animal. Cards are indexed under locality and marked-number, and no separate register is kept.

Each of the areas from which animals are marked is trapped systematically according to a prearranged plan, and the traps, which are usually left in each position for a working-week, are rotated so that the area is effectively covered about once a month and each trap-site is trapped once in about ten weeks.

Each area so trapped is referred to as an MR-experiment, and the principal experiments have been :

Sungei Buloh, Pylon area.—An area of open grassland (*Imperata cylindrica*) bounded by and contaminated with scrub, largely inhabited by *Rattus exulans*, *R. rattus jalorensis*, *R. r. argentiventer* and *R. whiteheadi* and visited by Wild Pigs (*Sus scrofa*). Trapping commenced in mid-1950 and continues.

Sungei Buloh, House Area.—The edge of an area of low-grade secondary forest, including both the woodland and the grassland. This is the area figured in Table III of Audy and Harrison, 1951. The species found were the same as for the last area, but in different proportions. This experiment was commenced in early 1950 and discontinued at the end of 1951.

Sungei Buloh, Stream Area.—A low lying area involving the flood-plain of the Sungei Buloh stream and the surrounding scrub-covered slopes, which had been abandoned by vegetable gardeners immediately before the experiment commenced. The whole area has been under cultivation in the past. It is inhabited by the same rats as the preceding areas. This experiment was commenced in late 1951 and continues.

The above "Sungei Buloh" areas are fairly close to the forest edge of the Bukit Lagong Forest Reserve in the neighbourhood of the Leper-Settlement. The settlement was built between 1925 and 1930 on the site of a small village, and much of the surrounding area was probably cleared of forest at that time.

Sungei Buloh, Forest.—An area of primary and secondary forest about a mile in from the edge of the Bukit Lagong Forest Reserve, including both the bottom and sides of the valley of the Sungei Buloh stream. The principal animals marked were *Rattus mülleri*, *R. sabanus*, *R. rajah*, *R. whiteheadi* and some squirrels. The experiment was commenced in mid-1950 and abandoned in mid-1951 owing to bandit activity.

Kuala Lumpur, Taylor Road.—The garden of a house in Kuala Lumpur, where the principal rat was *R. r. jalorensis*. This experiment lasted from mid-1950 to mid-1951. A popular account of this experiment has been published (Harrison, 1951).

Kuala Lumpur, Spooner Road.—This is a large area of *Melastoma*-scrub at the edge of the Lake Gardens in Kuala Lumpur, bounded by Spooner and Venning Roads. The only ground animals found have been *R. r. jalorensis* and the Monitor *Varanus nebulosus*. Macaque Monkeys (*Macaca irus*) and the Common Squirrel (*Callosciurus caniceps*) are the other principal inhabitants. The experiment was commenced in mid-1952 and continues.

Most of the work in connexion with these Mark-Release experiments is carried out by Mr. Haidzir bin Mat Isa, assisted from time to time by Mr. Johan bin Haji Adam.

THE ASSEMBLAGE OF HOSTS

It will be seen that the forest contains a large assemblage of host species, no one of which is specially abundant. With regard to our collection, it should be pointed out that "forest" includes not only virgin forest but also areas from which a certain amount of timber has been cut out, and areas which are being or have been used as gardens by the Aborigines.

When the forest is cleared most of the animals disappear with it, but some few animals seem to persist and adapt themselves to the altered conditions. Good examples of this process are the Wild Pig *Sus scrofa*, which is a major pest of the small cultivators ; and two squirrels,

Callosciurus caniceps (in the north) and *C. notatus* (in the south) which are abundant in village fruit trees and are even to be found in the gardens of town houses; and the Palm Civet *Paradoxurus hermaphroditus* (Malay "musang"), which is abundant in cultivated areas and even lives in the roof spaces of town houses as a rat predator.

Many of the animals which occur on cleared land, however, do not seem to be native to the forest. If they occur in forest at all it is in small numbers obviously associated with man's interference. Examples are the House Rat *Rattus rattus diardii*, the House Mouse *Mus musculus*, and the House Shrew *Suncus murinus*, all of which occur in or near houses, whether in town or village, and the Ricefield Rat (*Rattus rattus argentiventer*) which seems to be confined to areas of rice or of *Imperata*-grass, neither of which habitats can be considered natural ones. Presumably all these animals were introduced with man from outside Malaya. Rather more difficult to define is the position of the semi-domestic rats, *Rattus rattus jalorensis* and *Rattus exulans*. Both of these are abundant in areas of scrub and wasteland. *R. exulans* may invade houses, and *R. r. jalorensis* may become a major pest of such crops as Oil-Palm. Both may be found in secondary forest (unlike the more domestic pests) but their distribution leads one to suspect that they are of comparatively recent introduction, exploiting the areas of scrub created by man, and not fully at home in the native forest, although there seems to be no reason why they should not live there.

The species and groups of host animals which have been examined are set out in table 2 together with a tabulated summary of the numbers collected from each of the principal collecting areas. For the purpose of this summary "Town" comprises Kuala Lumpur as trapped by the municipal rat-catchers together with certain areas of wasteland and gardens which are actually in the town among the buildings. "Wasteland" includes both "Wasteland around Kuala Lumpur" and "Villages around Kuala Lumpur," since it is often difficult to decide precisely to which class a particular specimen should be allotted. The collection from "Oil Palm Estate" is also included in "Wasteland" except that the numbers of the dominant *R. r. jalorensis* are shown separately. "Forest" comprises all the forest collecting localities, and it must be remembered that in addition to primary forest, both disturbed and undisturbed, areas of secondary forest and of the Aborigines' gardens (*ladangs*) are included.

The principal host species recorded are :

RODENTS.

Squirrels.

Callosciurus caniceps (Gray) and *notatus* (Boddaert). These two squirrels are abundant in the understorey layer of forest and secondary forest, and come down to ground level freely. They range into scrub and cultivated country, and are well known in the gardens of town houses.

C. nigrovittatus (Horsfield) is more abundant than the last two in similar conditions in forest, but does not enter scrub.

C. tenuis (Horsfield) is a smaller squirrel than the others. It enters secondary forest but is not abundant there.

C. lowii (Thomas). Unlike the preceding species, this small squirrel seems to frequent the ground rather than the trees. It is confined to forest and is uncommon in our collection.

Lariscus insignis (Cuvier) and *Rhinosciurus laticaudatus* (Müller and Schlegel) are apparently entirely ground dwelling species. They occur in forest but are rare in our collections. The latter species is entirely insectivorous.

In addition to the squirrels included in the table, specimens of the following species have been examined, but in numbers too small to be worthy of inclusion : *C. hippurus*, a forest tree

squirrel ; *C. prevostii*, so far only seen in an Oil Palm estate ; *C. maclelandi*, a little squirrel almost confined to altitudes of over 1,000 metres ; and two species of *Ratufa*, giant-squirrels from the forest canopy.

Flying Squirrels of the following species, *Hylopetes sagitta*, *Petinomys genibarbis*, *Aeromys tephromelas*, *Pteromyscus pulverulentus*, and *Iomys horsfieldii*, are grouped together here. All are tree-top species largely confined to forest.

Rats and Porcupines.

Chiropodomys gliroides (Blythe) is a tree-dwelling mouse which seems confined to clumps of bamboo in forest and secondary forest. It is numerous in suitable localities and builds its nest inside the hollow stems.

Rattus canus (Miller) and *R. cremoriventer* (Miller) are tree rats, of similar habit to the *Callosciurus* squirrels, but, of course, nocturnal. They are confined to forest.

R. rattus (Linn.) in its three forms has been discussed above. *R. r. diardii* is a house rat, *jalorensis* a rat of scrub and woodland, particularly that provided by Oil Palm and Rubber estates, and *argentiventer* is a rat of grassland and rice fields.

R. exulans (Peale) is a rat of houses, grassland, and scrub.

R. annandalei (Bonhote) seems to resemble *R. r. jalorensis* in habit, but is rare in our collection, and has been found only at the edge of forest.

R. mülleri (Jentink) is the common giant ground rat of the wetter parts of the forest floor, such as valley bottoms.

R. bowersi (Anderson) another giant ground rat, is of similar habit to the last, but is uncommon in disturbed forest at the altitude of Kuala Lumpur. At higher altitudes it becomes more abundant.

R. sabanus (Thomas) is the common giant ground rat of the drier parts of the forest such as on the valley slopes.

R. whiteheadi (Thomas), a small spiny rat, is abundant on the floor of forest, secondary forest, and of the denser parts of scrub. Its preferences seem to be for the comparatively bare floor under thick head cover, whatever the height of that cover may be.

R. rajah (Thomas) is an abundant ground rat on the floor of forest. It exists in two forms, *R. r. surifer* and *R. r. pellax*, which are distinguishable on coat colour, but occur together.

Mus musculus (Linn.) is very strictly a house mouse. Nearly all of the specimens noted here were caught on sticky-board traps, and were consequently unsuitable for examination for parasites.

In addition to the above species of rat proper, specimens of the Bamboo rat, *Rhizomys sumatrensis*, and the porcupines *Atherurus macrourus* and *Hystrix brachyura* have been examined but their numbers are too small for inclusion in the table.

INSECTIVORES AND DERMOPTERA.

Tupaia glis (Diard) and *Tupaia minor* Gunther, the greater and lesser tree-shrews, are abundant in forest, secondary forest, and scrub. Despite their squirrel-like appearance, they seem to be very largely ground dwelling animals which venture freely into the trees. The rare nocturnal and arboreal *Ptilocercus lowii* (pen-tailed shrew) has been examined, but in small numbers only.

Suncus murinus (Linn.) is primarily a house shrew and is rarely trapped far from houses. Species of *Crocidura* have been trapped in forest, secondary forest, and scrub, but in very small

numbers only. Our impression is, however, that this is a fault of the technique of trapping rather than a deficiency in numbers.

Hylomys suillus (Miller) a short-tailed shrew, and *Echinosorex gymmurus* (Raffles), the piscivorous Moonrat, are both rare in our collections and apparently confined to forest. The latter species is found on the banks of forest streams.

Cynocephalus variegatus (Audebert), the Flying-Lemur, has been examined but only in small numbers. It is reasonably common in forest and is, of course, strictly arboreal.

BATS.

PTEROPIDAE, the Flying Foxes and Fruit Bats of some twelve species, are abundant in forest and scrub.

RHINOLOPHIDAE, the Horseshoe Bats, of which there are some forty species, are abundant in caves, conduits, and hollow trees, in both forest and wasteland.

MEGADERMATIDAE, the False Vampires, of which there are only two species, are reasonably common in open country.

MOLOSSIDAE, two of the six species have been examined, both from hollow trees in the forest.

EMBALLONURIDAE. Specimens of *Emballonura monticola* have been examined from forest. During the period under review none of the cave dwelling species of *Taphozous* (Tomb Bats) have been examined from the areas mentioned, but specimens from a cave on the island of Seletar, a small island off the coast, have been examined.

VESPERTILIONIDAE. A large number of the fifty or so species of these little bats have been examined. They are abundant in situations of all kinds from roof spaces to the unrolling leaves of forest trees.

PRIMATES.

Macaca irus, the Long-tailed or "Crab-eating" Macaque monkey is abundant in forest, scrub, and even in the gardens of Kuala Lumpur itself.

Pithecus femoralis, the commonest of the Leaf Monkeys, is abundant in forest and secondary forest, but does not approach human habitations as closely as does the last species.

Specimens of *Nycticebus coucang*, the Slow Loris, have also been examined.

CARNIVORES.

Paradoxurus hermaphroditus, the Common Palm Civet, is not only abundant in forest, but has become a domestic pest, living in the roof spaces of houses and in the surrounding trees, and feeding on fruits, lizards, rats, etc.

Among other carnivores which have been examined are the Civets *Paguma larvata* and *Arctogalidia trivirgata*, the cat *Felis bengalensis*, and species of otter.

OTHER ANIMALS.

A few Mouse Deer, *Tragulus* spp., Wild Pig, *Sus scrofa*, and the Pangolin or Scaly Anteater, *Manis*, have been examined.

Snakes, of some sixty odd species from a variety of habitats, have been examined.

Tree Lizards, mostly species of *Gonocephalus*, are abundant in forest and secondary forest.

Geckoes recorded are mostly specimens of the giant *Gekko*, abundant on forest trees.

Skinks of the genera *Lygosoma* and *Mabuya* are abundant on the ground of both forest and wasteland.

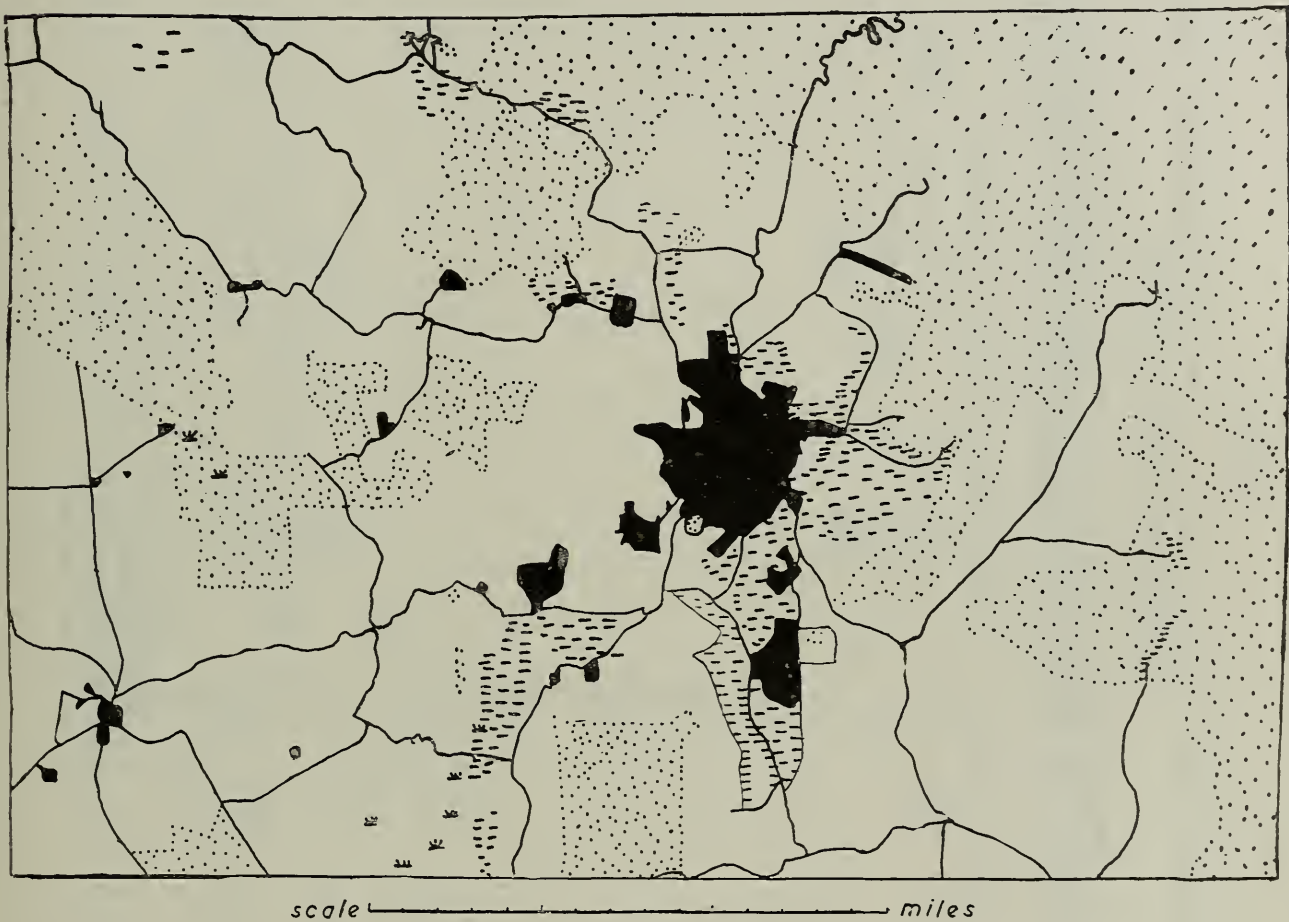
Monitor Lizards of the genus *Varanus* are abundant in forest and scrub. They are primarily ground lizards which climb readily.

Ground Birds, largely Quail, Rails, and Crow Pheasants, bear large mite infestations. A wide range of species of birds has been examined, but only the ground birds are included here.

Fig 3

Land usage in Selangor

(illustrating the Table on p. 3)



A 900 square mile area around Kuala Lumpur illustrating the vegetation mosaic set out in Table I:

Forest	dotted.
Plantations	blank.
Towns (built up)	solid black.
Mining areas	cross stripes.

In a map of this scale it is not possible to illustrate the smaller details of the mosaic.

TABLE 2
SUMMARY OF COLLECTIONS MADE IN MALAYA BY THE COLONIAL OFFICE SCRUB TYPHUS
RESEARCH UNIT, 1948-1952.

The relative degrees of abundance of chiggers in each group are indicated by (.) for occasional or rare infestation, and +, ++, or +++ relating to relative abundance within each chigger-group (i.e. these indications may be compared vertically but only very roughly horizontally between groups). In the case of the vectors, the incidental infestations indicated by (.) are of such a low order that they may have been picked up by only very occasional and temporary contact with the ground. The heavier infestations by the vectors are shown in bold type because they represent much larger populations than are found on the other species (see p.17).

Hosts	Number examined from :			Relative abundance of infestation by trombiculids :					Percentage of hosts infested by :						
	Town	Waste-land	Forest	Vectors	<i>Trombicula</i> &c.	Others	<i>indica</i> group	<i>Euschongasia</i> and <i>oudemansi</i> groups	Others	Gahrlepiinae	Trombiculids	Parasitoids	Ticks	Lice	Flies
SQUIRRELS															
<i>Callosciurus caniceps</i>	...	3	196	.	-	-	-	+	-	.	21	22	5	16	13
<i>C. notatus</i>	...	1	312	.	-	-	-	+	-	.	49	22	1	11	13
<i>C. nigrovittatus</i>	...		442	.	-	-	-	+	-	-	80	22	3	5	24
<i>C. tenuis</i>	...		154	.	-	-	+	+	-	.	82	31	18	10	15
<i>C. lowii</i>	...		26	.	-	-	-	+	-	-	-	-	-	-	-
<i>Lariscus insignis</i>	...		31	+	+	-	-	+	+	+	53	2	0	1	1
<i>Rhinosciurus laricaudatus</i>	...		43	+	+	-	-	+	+	+	-	-	-	-	-
Flying Squirrels	...		19	-	-	-	-	+	+	-	-	-	-	-	-
RATS															
<i>Chiropodomys gliroides</i>	...		332	-	-	-	-	.	-	-	0	50	0	1	1
<i>Rattus canis</i>	...		172	.	-	+	+	+	+	-	78	33	1	8	6
<i>R. cremoriventer</i>	...		258	-	-	-	-	.	-	-	2	84	3	14	3
<i>R. rattus diardii</i>	...	437*		.	-	-	+	+	.	.	44	24	1	4	32
<i>R. r. jalorensis</i>	...	374	232	+	+	+	+	+	.	.	72	51	4	8	7
	...	1357§		+	+	.	+	+	.	.	88	34	4	6	5
<i>R. r. argentiventer</i>	...	442	2	+	+	+	+	+	.	.	83	35	2	12	5
<i>R. amandalei</i>	...		15	+	+	+	+	+	.	.	-	-	-	-	-
<i>R. exulans</i>	...	627	503	.	-	.	.	.	-	.	16	41	1	4	1
<i>R. mulleri</i>	...		420	+	+	.	.	+	+	.	85	87	9	10	7
<i>R. bowersi</i>	...		92	+	+	+	.	+	+	+	82	36	13	13	20
<i>R. sabanus</i>	...		919	.	.	.	.	.	-	+	63	55	9	4	8
<i>R. whiteheadi</i>	...	69	467	.	.	.	.	.	.	+	39	85	1	21	5
<i>R. rajah</i>	...		532	.	-	.	.	.	.	+	23	85	5	7	5
<i>Mus musculus</i>	...	924†		.	-	.	.	.	.	+	-	-	-	-	-

* Mostly in village houses.

§ From Oil Palm Estate.

† Caught in sticky-board traps.

TABLE 2—(cont.)

SUMMARY OF COLLECTIONS MADE IN MALAYA BY THE COLONIAL OFFICE SCRUB TYPHUS RESEARCH UNIT, 1948-1952—(cont.)

Hosts	Number examined from :			Relative abundance of infestation by trombiculids						Percentage of hosts infested by :			
	Town	Waste-land	Forest	Vectors	<i>Trombicula</i> &c.	Others	<i>indica</i> group	<i>Euschongastia</i> &c.	Others	Gahrlep- iinae	Trombiculids	Ticks	Lice
INSECTIVORES													
<i>Tupaia glis</i> ...	...	...	130 } 83 }	+	.	+	+	+	+	+	51	5	4
<i>T. minor</i> ...	...	...	34	-	-	-	-	-	-	-	0	0	1
<i>Suncus murinus</i> ...	...	901	36	+	+	.	.	.	.	+	+	+	+
<i>Crocidura</i> spp ...	...	...	20	+	+	+	+	+	+	+	+	+	+
<i>Hylomys suillus</i> ...	...	...	11	.	-	-	-	-	-	-	+	+	+
<i>Echinosorex gymmurus</i> ...	...	...	...	...	...	...	...	...	...	...	...	...	...
BATS													
Peropodidae ...	...	70	125	-	-	-	-	-	-	-	+	+	+
Rhinolophidae ...	...	3	849	-	-	+	+	-	+	+	+	0	0
Megadermatidae ...	...	...	34	-	-	-	-	-	-	-	+	+	+
Molossidae ...	...	38†	18	-	-	+	+	-	-	-	+	+	+
Emballonuridae ...	...	...	522	-	-	-	-	-	-	-	+	+	+
Vesperilionidae ...	...	...	...	...	...	...	...	...	...	...	...	...	...
OTHER ANIMALS													
<i>Macaca irus</i> ...	...	3	...	...	...	...	...	...	...	...	+	+	+
<i>Pithecius fenoralis</i> ...	...	2	...	...	...	...	...	...	...	...	+	+	+
<i>Paradoxurus hermaphroditus</i> ...	...	23	9	-	+	-	-	.	.	-	+	+	+
Snakes ...	...	...	165	-	-	-	-	-	-	-	+	+	+
Tree lizards ...	...	71	225	-	-	-	-	-	-	-	+	+	+
Geckoes ...	...	4	35	-	-	-	-	-	-	-	+	+	+
Skinks ...	...	6	15	-	-	-	-	-	-	-	+	+	+
Monitor lizards ...	...	4	14	-	-	-	-	-	-	-	+	+	+
Ground Birds ...	...	3	70	+	+	+	+	+	+	+	63	50	0

† *Taphozous* from cave on Sektan Island.

THE ASSEMBLAGE OF ECTOPARASITES

Preliminary check-lists of trombiculids were published in the Annual Report of the Institute for 1951 (pages 89-97). A total of 92 species were listed from Malaysian sources, from material examined up to the end of 1952. The following species have since been added to this list, bringing the total up to 124: *Trombicula* (*Leptotrombidium*), 6; *T.* (*Neotrom.*), 1; *Fonsecia*, 1; *Euschöngastia* sens. lat., 7; *Doloisia* sens. lat., 4; *Walchiella*, 1; *Gahrlepiea* (*Walchia*), 1; *G.* (*Schöngastiella*), 2; *G.* (*Gahrlepiea*), 1; *G.* (*Gateria*), 2; *Whartonia*, 2. Species in the check-list numbered 88, 89, 91 are provisionally to be ascribed to *Whartonia* not *Hannemania*. Species numbered 9, 10, 15, 33, 35, 46, 47, 48, 49, 53-55, 75, 76, 90, 92, have been described in the present collection of papers (Traub and Audy, 1953 *ab*, Traub and Evans, 1953, Womersley, 1953) while numbers 20, 31 and 77 have been described as *E. dimolinae*, *E. revelae* and *Schöngastiella hipposideros* by Audy (1952).

Table 2 gives a general impression of the degree of infestation of the various hosts by species or groups of trombiculid mites. The first three columns give the number of hosts examined from the three major habitat groups, but the mites from all these hosts have not been identified—the numbers for various hosts for which this has already been done are shown in Table 3. The relative abundance of infestation by various trombiculids is shown for the following:

Subfamily Trombiculinae

Trombicula and related genera

Vectors of scrub-typhus: *T. akamushi* and *T. deliensis* (which have different distributions, as shown in Table 3).

Other species of the subgenus *Leptotrombidium*, which includes several species (e.g. *T. sylvestris*) closely related to the vectors.

Species other than the above

Euschöngastia and related genera

The *E. indica* group, of which *E. indica* is dominant outside, and *E. audyi* inside, the forest. Other species in this group occur, but rarely.

The *E. lacunosa* group and the (*Walchiella*) *oudemansi* group.

Species other than the above.

Subfamily Gahrlepiinae (Walchiinae) (the genus *Walchiella* is excluded from this subfamily by us, being provisionally placed as a subgenus of *Euschöngastia*.)

The last five columns refer to major groups of parasites (trombiculid mites, parasitoid mites, ticks, lice, and fleas). The trombiculid mites and ticks remain attached for definite periods of time so that the mean number of these parasites per individual host is an important index of abundance (but see comments below). The parasitoids and fleas are however particularly prone to leave their hosts and actual numbers of these found on hosts in the prevailing conditions of collection are not particularly significant. For this reason, the infestations are here presented as a percentage of hosts infested.

Table 3 gives details of the actual numbers of the commoner species of trombiculids on the commoner hosts which have been adequately studied. A similar but less accurate table was given by Audy and Harrison (1951, p. 377). In interpreting this table, three adjustments must be made. Firstly, the commensal rats—*R. r. diardii* in villages and towns, *R. r. argentiventer* in open fields and waste-land, and *R. r. jalorensis* in oilpalms and wooded waste land, as well as *R. exulans* and the several species on islands—all occur in large numbers which are not rivalled, and often not even approached, by the less dense populations of other species occurring in the forests. Therefore, any given degree of infestation of these rats is more significant as an indication of mite-population than it would be with the other more thinly

TABLE 3

INFESTATION OF CERTAIN ANIMAL HOSTS BY THE COMMONER TROMBICULID MITES

Only animals which have been reasonably well sampled are included in this table. The figures in the columns show the mean numbers of trombiculid larvae found per individual host, trivial infestations being shown by a dot.

Hosts, and number examined			Mean number of Trombiculids per Individual											
			Trombicula					Euschöngastia				Gahrliepia		Other species
			Total, all species	<i>deliensis</i>	<i>akanushi</i>	Other <i>Leptotrombidium</i>	<i>munda</i>	<i>spicea</i>	<i>indica</i>	<i>audyi</i>	<i>lacunosa</i>	<i>oudemansi</i>	<i>Walchia</i> , <i>Gahrliepia</i> , <i>Gateria</i>	
ARBOREAL ANIMALS														
Squirrels														
<i>Callosciurus caniceps</i> 96	...	3							3					
<i>C. notatus</i> 207	...	11	.			.		10		.				.
<i>C. nigrovittatus</i> 300	...	39						38						
<i>C. tenuis</i> 61	...	30	.				3	11	14	2				.
Flying Squirrels 11	...	+						+	+	+				.
Tree Rats														
<i>Chiropodomys gliroides</i> 76	...	0												
<i>Rattus canus</i> 112	...	38				.	1	1	3	.	11			22†
<i>R. cremoriventer</i> 72	...	.						.						
Tree Shrews*														
<i>Tupaia</i> spp. 102	...	37	5		1		2	2	4	4	9	7		3
TERRESTRIAL ANIMALS														
Ground Squirrels														
<i>C. lowii</i> 13	...	(10)								(10)				
<i>Lariscus</i> and <i>Rhinosciurus</i> 29		31	10			.				10	2	2		7
Ground Rats														
<i>R. rattus jalorensis</i> 241	...	22	5	10	.		.	3	1	.	1			3
" " " (oilpalms) 1,288		49	10	1		.	.	37	.	0	.			1
<i>R. r. argentiventer</i> 387	...	81	19	59				1	.		.			2
<i>R. exulans</i> (field) 650	...	2	1	.				1			.			.
<i>R. mülleri</i> 175	...	46	14		1					3	25	2	1	.
<i>R. bowersi</i> 54	...	85	22		36					.	19	5	1	2
<i>R. sabanus</i> 450	...	12	2		1			.		5	.	1	2	.
<i>R. whiteheadi</i> 371	...	7	.					.				7	.	.
<i>R. rajah</i> 271	...	3	.					.	.	.		2	.	.
Insectivores †														
DOMESTIC SPECIES														
<i>R. rattus diardii</i> (K.L.) 2,439		19				.		19						
<i>R. norvegicus</i> (seaport) 824	...	10						10						
<i>Suncus murinus</i> 484	...	0												
<i>Paradoxurus hermaphroditus</i> 7		0												

* Tree Shrews are as much terrestrial as arboreal

† The Insectivores comprise the largely arboreal Tree Shrews, the house-haunting *Suncus murinus*, and a number of less common species, including *Crocidura* spp. and *Hylomys suillus* (usually brought in dead,) and *Echinorex gymnurus* (of which too few have been examined.)

‡ Mostly the host-specific *Ascoschöngastia malayensis*.

dispersed hosts. Secondly, the vector species *T. akamushi* and *T. deliensis* at least have a particularly short feeding-time, many other common species taking several times longer to complete their feed on the host. The number of vector mites occurring on various populations of hosts must therefore be multiplied accordingly before populations which they represent can be compared with the populations represented by the infestation data for most of the other important species.

A third adjustment must be made to allow for the short feeding-time of the vector species and the particular conditions of collecting. Many of the forest animals collected by the aborigines spend a day or even two days in the trap before they reach the laboratory. The exact time spent in the traps is often difficult to discover, but sampling surveys suggest that about one-third of the animals have been trapped during the night before delivery, one-third during the previous night, and the remaining third during the night before that. Applying the known feeding-times of the mites (Harrison 1953, this *Study* p. 171) to these estimates we conclude that the observed infestation rates by *T. deliensis* should be multiplied by one and a half, whereas most of the other mites, being of longer feeding-time, will be very little affected.

Interpreted in the light of these three adjustments, it is clear that the vector mites associated with the commensal rats occur in enormously greater numbers than do any other trombiculid mites in the area investigated. This has also been suggested by investigations made elsewhere, as for example in Imphal in 1945, and it would probably be safe to generalise this observation over the area of distribution of the vectors, excepting possibly in those places where their distribution overlaps with that of various species of trombiculids causing scrub-itch. Table 3 is discussed elsewhere in this study in relation to the taxonomic and ecological relations of these mites (Audy 1953b).

MISCELLANEOUS COLLECTIONS

The major collections from North Borneo and Sarawak, in collaboration with Traub and Tom Harrison, are not discussed here. A survey has been made outside Selangor each year, in several cases in the interests of the armed services. Several more such surveys are planned for the time when certain areas will be free from bandits. The following four surveys were particularly intensive; a number of lesser ones have also been carried out.

Abandoned Pineapple Estate, Kota Tinggi, Johore

(10 days—January, 1948)

Description—Approximately 5,000 acres of overgrown pineapple estate surrounded by forest at mile 17, Johore Bahru to Kota Tinggi road, in the extreme south of the peninsula. This was to be an important military training centre, and a combined malaria and scrub-typhus survey was carried out. All three officers of this unit, supported by three assistants, and by Captain Hooper, R.A.M.C., and two R.A.M.C. other ranks from the School of Hygiene at Singapore, were occupied on the typhus survey between January 12 and 21, 1948.

The area had been cleared of forest and planted with pineapples between 1932 and 1934. This usually leads to a good deal of soil erosion. In 1940-41, roughly the eastern half of the plantation was allowed to revert to scrub under "regeneration control": lalang grass was weeded out at 6-monthly intervals. Pineapple growing continued during the Japanese occupation in a desultory fashion at the extreme west section. A small village grew up round a sawmill in the centre of the estate, 3 miles from the main road; from it a road goes deeply into the forest.

At the time of our visit, the estate, comprising low hills rising 100-200 feet (to 2-300 ft. altitude), was mostly covered with 4-6 foot high "bracken" (*Gleichenia*) undergrowth, with young trees along the watercourses, especially *Adinandra dumosa* which is characteristic of

secondary vegetation. There were signs of terracing in places, with occasional etiolated pineapple plants hidden in the bracken. The soil on the hillslopes was poor, shallow, and lateritised. Geologically, the estate was on mesozoic granites and allied rocks, which tend to give an acid soil on weathering. In a few places, some lalang was to be found.

There had been no record of scrub-typhus from this particular estate, but there had been a few post-war cases from the neighbourhood of Kota Tinggi (? neglected estates).

Investigations—Attempts were made to collect potential hosts and estimate their numbers and distribution, to collect vector mites from the soil at representative sites, as well as from trapped hosts, and, in the event of positive findings, to compare the mite infestation in the Estate with that in the forest fringe, and to attempt to recover infection from the mites.

The following animals were either trapped or recorded by such evidence as droppings, footmarks, and noises : elephant ; wild-pig ; tiger ; the darkhanded gibbon ; one *Echinosorex gymnurus*, moonrat ; *Suncus murinus*, house shrew ; two *Rattus exulans*, little house-rat ; three *R. rattus diardii*, the Malayan house-rat ; two *R. rajah*, a spiny rat.

Hosts : 40 cage-traps, 9 non-return treadle traps, and 50 break-back traps were used for a total of 542 trap-nights. The total result was 7 rats and one moonrat ; a trapping rate of little over 1 per cent. A total $4\frac{1}{2}$ hours of night prowling produced no mammals whatever. It was clear that, at the time, the population of small mammals in the area was surprisingly low—so low that the rat population may recently have had a violent reduction (“crashed”) which would account for the lack of lesser predators also.

Mites : no trombiculids were found on the 7 rats and the moonrat trapped. There had been ample rain—we had indeed been stranded by floods for five days en route to the estate. Soil samples, taken from 6 representative sites, were examined by flotation. From over 100 samples, each approximately a square foot, 3 inches deep, a few trombiculid and bdellid mites, and two cyphophthalmids were found, all these being predatory. No trombiculids were found. The absence of trombiculids of any species from this large number of selected samples is sufficiently unusual to demand explanation. The scarcity of mammal hosts also appeared to be remarkable. Had this scarcity obtained throughout the history of the Estate, this would suffice to explain the absence of mite colonies in the areas examined, except for the lalang patches near habitations. Other factors may have contributed : (1) Lack of introduction of mites such as the vector which thrive in the open, because the Estate is somewhat cut off from extensive tracts of scrub ; (2) the bracken may have offered very little attraction to small mammals ; (3) there may have been undetermined factors in the soil discouraging trombiculid nymphs and adults (e.g. high pH, general poverty of soil fauna, number of arthropod predators, possible inimical fungi).

Although it could not be assumed that no foci of scrub-typhus existed on the Estate, it was assumed that the risk was so small that no particular preventive steps need be taken. Further attempts to trap rodents and shrews during the early days of occupation of this area would enable this impression to be strengthened or revised, and this action was recommended. No cases have been recorded from this estate up to date.

Reserve near Port Dickson, Negri Sembilan

(October-November, 1949)

Description.—The HQ of the Malay Regiment is off the coast road south of Port Dickson, Negri Sembilan. There have been cases of scrub-typhus in this area both before and since the war. A large military campsite was selected in 1949, covering about 1 square mile, and a mile directly inland behind the Malay Regiment HQ and including part of the Sungei Menyala Forest Reserve, sections of old rubber plantation, and secondary vegetation.

Investigation.—Mr. Ensoll and one junior assistant started collecting in this area on October 4. They were joined by Mr. Nadchatram on October 17, and the party remained until November 8. An attempt was made to collect hosts from several representative areas which had been selected during a preliminary inspection followed by a study of air photographs of the area. A senior officer paid two visits to the area and the military malaria-survey personnel gave a considerable amount of help. Transport was provided by Malaya District HQ.

The following table (Table 4) gives details of the collection. An attempt was made to recover infection from a number of larvae of *T. akamushi* taken from several rats; Dr. Savoor reported a negative result.

TABLE 4

DETAILS OF MITE-INFESTATION AT THE S. MENYALA F.R. AREA, SHOWN AS THE NUMBER OF INFESTED HOSTS FOLLOWED BY THE TOTAL NUMBER OF MITES OF EACH NAMED SPECIES.

Host species	Number examined	<i>T. akamushi</i>	<i>T. deliensis</i>	<i>Euschöngastia audyi</i> , etc.	<i>W. lewthwaitei</i>	Others
<i>R. r. argentiventer</i> :						
from behind military Camp ...	17	6(462)			4(19)	
from proposed site ...	39	4(28)	3(111)	2(3)	1(23)	
<i>R. r. jalorensis</i> (mostly from Camp area) ...	11	9(198)		1(21)		
<i>R. r. diardii</i> ...	1					
<i>R. exulans</i> ...	20	3(11)*	1(2)		12(370)	1(1) <i>E. indica</i> 1(2) <i>W. enode</i>
<i>R. whiteheadi</i> ...	4				1(13)	
<i>R. amandalei</i> ...	1					
<i>Tupaia glis</i> , tree shrew ...	2					1(90) <i>G. fletcheri</i>
<i>Callosciurus</i> species (20 <i>notatus</i> ; 1 <i>nigrovittatus</i> , 1 <i>tenuis</i>) ...	22			11(127)		
Birds:						
<i>Hypotaenidia striata</i> , rail ...	1	1(25)				
<i>Turnix suscitator</i> , quail ...	3	3(286)(one with 246)				
<i>Excalfactoria c. chinensis</i> , button quail ...	2	1(17)				

* 10 of these vector larvae came from 2 rats in grass from the Malay Regiment Camp area.

Islands in the Malacca Straits

(10 days—January, 1950)

A full account of this investigation has been published (Audy *et al.* 1950). A reconnaissance survey of Jarak Island, which lies almost in midchannel 40 miles from the coast, was carried out because of an outbreak of scrub-typhus in a museum expedition there in 1932 and also because of reports of what appeared to be scrub-itch there. The only mammals found on the island were a fruit-bat (in small numbers) and an overcrowded and sickly population of *Rattus rattus jarak* (which appears to be a local feral representative of *R. r. diardii*). All the rats were infested by *Trombicula deliensis* (average about 200 per rat), and a number were also infested by *Walchia rustica* (attached to the chins), parasitoid mites, and worms. Ticks (as yet unidentified) were present but confined to the skinks which were quite common on the island. All appearances suggested an entirely introduced fauna and flora, i.e. of an oceanic rather than continental type.

No rickettsial infection was recovered from about 300 larvae of the vector from this island. In the circumstances, this negative result is surprising and demands further investigation.

Bat cave on Pulau Seletan.—The twin rocky islets Angsa and Seletan, near Port Swettenham, were visited on the return journey and a number of Tomb Bats (*Taphozous melanopogon*) were shot. Some of these were infested by *Trombicula taphozous* Wom., *T. insolli* Philip & Traub, and a few specimens of *T. deliensis*.

Nicobar Islands

(14 days—October, 1950)

Arrangements were made in 1950 for collections to be made in Car Nicobar where there were several scrub-typhus casualties among Japanese troops in 1944. We are very grateful to the Government of India for permission to do this, and to the Royal Air Force, who have a station on the island, for their collaboration. In October, 1950, Dr. C. A. Gibson-Hill of the Raffles Museum spent a fortnight on Car Nicobar and the very interesting collection he made on behalf of the unit was received in 1951.

Dr. Gibson-Hill trapped widely both in the scrub which covers much of the island and in the huts of the islanders, catching 76 rats in all. The 24 rats from the huts, which were beehive-like structures raised on poles, were of a pale-bellied form of *Rattus rattus*. Of the 52 rats trapped in scrub, grassland, and R.A.F. camp, and the island store or shop, 51 were of a dull-bellied form of *Rattus rattus*, and one was a *R. mülleri* of a slightly smaller size than that common in Selangor. The identification of the *R. mülleri* has been confirmed by Sir John Ellerman.

It is noteworthy that the distribution of the pale and dark-bellied forms of *Rattus rattus* reversed the usual order. In Malaya, as in most countries, the dark-bellied form (*R. r. diardii*) is a house-rat and the pale-bellied form (*R. r. jalorensis*) does not enter houses. The dark-bellied scrub rat of Car Nicobar is perhaps analogous to the dark-bellied *R. r. jarak* of the forest floor of Jarak Island (probably a feral house-rat), and the pale-bellied rat of the stilt-houses is probably analogous to the white-bellied *R. r. khyensis* of Rangoon, which although primarily a garden tree-rat does enter houses, there apparently being no dark-bellied *R. rattus* to compete with it.

Only two species of trombiculid mites were found on these rats. The vector *Trombicula deliensis*, was common on the pale-bellied rats from stilt-huts (nine out of 24 rats bore 440 vector mites). This compares with the heavier infestations found on the wood-rat *R. r. jalorensis* in Selangor. Of five dark-bellied rats trapped in the island "store" two were infested by 4 *T. deliensis* and 22 *Euschöngastia indica*, which is the dominant mite on house-rats in Selangor.

Summary

1. A routine collection of over 21,000 vertebrates, made in Malaya between 1948 and 1952 by the Colonial Office Scrub Typhus Research Unit, comprised some 115 species of mammals, 30 species of birds, and 90 species of reptiles and amphibians. The collecting areas are here described, and also the method of collection both of the animals and of their external and internal parasites.

2. A brief account is given of the principal hosts and their habitats.

3. The distribution of the principal species of trombiculid mites on these hosts is shown in some detail, and gross infestation figures are given for the major groups of ectoparasites.

4. A brief account is given of additional small collections from two localities on the mainland, from islands in the Malacca Straits, and from the Nicobar Islands.

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MALAYSIAN PARASITES II

PRELIMINARY NOTE ON THE INCIDENCE OF WORM INFECTION IN COMMON HOSTS

By

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Definition of Terms

It would be proper to define here the terms used in this and following helminthological papers. The terms *worm* and *helminth* are group names without strict zoological connotation and are used here as synonyms and refer to members of the Acanthocephala, Nematoda, Cestoda and Trematoda. The word *helminth*, however, seems to be generally preferred by parasitologists because it excludes the Annelids and worm-like Arachnids from consideration.

In recent years, it has been suggested by certain parasitologists that one should limit the use of the word *infection* to those organisms, such as bacteria and protozoa, which are capable of indefinite multiplication within the host, and *infestation* to those parasites which do not so multiply such as worms and insects. Owing to the confusion in usage of these words by medical men and parasitologists the matter was referred by the American Society of Parasitologists to a Committee on Terminology. Although any attempts at legislation would be unwarranted the views of such a Committee can be informative and advisory. Hertig, Taliaferro and Schwartz (1937) who constituted the Committee reported that the terms *infection* and *infestation* refer to processes undergone and effects produced by parasites rather than to the nature of systematic position of the organisms themselves. In the invasion of the host and subsequent establishment of parasites the phenomena involved in resistance, susceptibility, dosage, host-specificity, virulence and the like, exhibit so many fundamental similarities for the various groups of organisms concerned, that it seems awkward to use first one and then another term for the same process or condition. They recommended that *infestation* ought to revert to its original use in connection with external, and in most cases visible, agents such as insects. In fact, they said they "fail to see any reason for continuing the use of the term *infestation* as applied to internal parasites and believe that the present confusion will disappear only if its use be discontinued." The term *infection* should properly be applicable wherever the parasite invades and establishes itself within the body of the host, including the gastro-intestinal tract. For conditions which do not lie clearly in either category, such as those involving the Sarcopitoid mites, and maggots in ulcers or external orifices, etc., they suggested that the terminology could well be left to the judgment and taste of the author.

Historical Summary

No systematic survey of the parasitic worms of Malaya has ever been undertaken but that does not mean that no information is available or that no interest is evinced by Medical and Veterinary Officers about this important group of organisms.

Worm Parasites of Man.—As long ago as 1893, Kirk gave an analysis of 150 cases of local fever in the Journal of the Straits Medical Association. He considered that ankylostomiasis was widespread and responsible for a large amount of sickness and mortality among the cooly class and that a chronic febrile condition was often a main symptom of this infection. He deplored the fact that the disease was rarely diagnosed owing to the neglect of a systematic examination of the faeces. Daniels (1905) discussed the importance of the importation of parasites like "*Filaria Bancrofti*" by immigrants from India and China.

A Commission was sent out by the Rockefeller Foundation to the Orient in 1915 to determine to what degree *Uncinaria* infection is a menace to the health and working efficiency of the people of the country under consideration. The report drawn up by Darling, Barber and Hacker (1920) contains a fund of detailed information. Great impetus was given to general sanitation and control of hookworm disease as a result of the survey of hookworm infection in the Straits Settlements (Singapore, Malacca and Penang) commenced by Barnes and Russell of the Rockefeller Foundation in co-operation with the Medical Department. They introduced the Willis-Molloy flotation technique for the examination of faeces which is still used as a routine diagnostic method in the clinical laboratories of Malayan hospitals.

Strahan and Norris (1934) reported that elephantiasis was prevalent in North Province Wellesley and the present writer identified *Microfilaria malayi* Brug, 1927 from blood films sent by them. Subsequent researches by Poynton and Hodgkin (1938) showed that filariasis was endemic in the low lying areas where the big rivers run to the sea and that *Mansonia longipalpis* and *M. uniformis* were mainly concerned in transmission. Polunin (1951) found endemic filariasis in widely spread areas of the Malayan hinterland both among the Aborigines and the Malays.

Buckley (1938) investigated the cause of "sawah-itch" a dermatitis among the rice-cultivators of Negri Sembilan, and incriminated the cercaria of *Schistosoma spindale* Montgomery, 1908. The writer (this *Study*, p. 195) has recently found that cercarial dermatitis in Malaya can also be caused by cercaria of the "Elvae" group.

The Annual Reports of the Medical Department record findings of routine stool examinations but these do not give an accurate picture of the incidence of worm infections in Malaya. The writer examined one portion from each of 1,300 faecal samples sent to the routine laboratory from patients at the General Hospital, Singapore. On comparing results it was noted that whereas the Willis-Molloy method is efficient in detecting hookworm infection, it is less reliable for *Ascaris* and *Trichuris* infections. When only unfertilised eggs of *Ascaris* are present it is seldom detected by the salt flotation technique while *Clonorchis* (imported), *Schistosoma* (imported) and *Strongyloides* infections are never reported upon although *Clonorchis* eggs were present in 2.5 per cent and *Strongyloides* larvae in 6.0 per cent of these patients. Less than 2 per cent of these patients had sought admission to hospital for treatment of helminthiasis. An examination of 150 faecal samples from members of the public belonging to the same social class showed a close similarity to the findings of hospital patients. This suggests that the incidence of hookworm, *Ascaris* and *Trichuris* infections reported by hospitals gives some indication of their incidence among the population as a whole.

The war introduced several factors which are likely to have altered the incidence and infection rates of worm parasites among the Malayan people. Among these may be mentioned the large influx of troops into Malaya from north India and Japan, the return from Siam and Burma of Malaysians who had gone there as forced labour, the low nutritional state that was prevalent during the war and for some time after, and the general deterioration in sanitary standards.

Worm Parasites of Animals.—On the veterinary side, Ford (1902) published an account of "Aortic Worms" in the Veterinary Record and Gnoh Lean Teck (1905) made a more extended study of these in buffaloes and oxen. Daniels (1905) listed a number of worms from domesticated animals and discussed their importance. Purvis, Orr, Joseph, Narayanan, Lancaster, and other Veterinary Officers in Malaya made extensive collections of parasitic helminths, which have been studied by themselves and by others like Adams (1932) and Robinson (1934). Buckley (1937-8) described *Stephanofilaria kaeli* from the "Krian sore" of cattle and incriminated certain species of *Culicoides* as carriers of *Onchocerca gibsoni*.

The worm parasites which are of no obvious medical or veterinary importance have been largely neglected in Malaya. A few records exist of parasitic worms collected from Malayan hosts which have found their way into the Zoological Gardens in other parts of the world. The writer (1950, 1951) reported on parasites of certain Primates, including the Orangutan, and a series of observations on Malayan worm parasites is included in this *Study* (p. 195, Sandosham 1953*ab*). The Colonial Office Scrub Typhus Research Unit has published a preliminary note on worms from rats from Jarak Island (Audy *et al.* 1950, p. 256). The following were common : *Capillaria (Hepaticola) hepatica*, *Rictularia* sp., a *Nippostrongylus* sp. (J. J. C. Buckley *det*), and peculiar strongyloids which were found in the liver.

Present Studies

A survey to establish the present-day infection rates of the common human worms and to determine the parasites of domestic and wild animals is being undertaken in the Department of Parasitology of the University of Malaya and the writer hopes to publish shortly a check-list of worm parasites recorded in this country.

The Colonial Office Research Unit is investigating the biology and ecology of carrier mites and their animal hosts. Collecting small mammals, especially rats and insectivores, and identifying the ectoparasites is fundamental to the whole scheme of this investigation. Opportunity has been taken to make a thorough and complete examination of as large a number of each species as possible of these animals for endoparasites. These worm parasites are in the process of being sorted out but it is felt that the Table below, giving the total numbers of endoparasites grouped as Nematodes, Cestodes, Trematodes and Acanthocephala, for each species, will be of some value in assessing the degree of worm infection in these hosts. As yet, the number of hosts examined, with the exception of a dozen species, is too few to enable sound conclusions to be drawn on the intensity of infection. Even so, a glance at the Table suggests that the rats of the woods and forests like *Rattus rattus jalorensis*, *R. whiteheadi*, *R. mülleri* and *R. rajah* are less heavily parasitised than the house-frequenting forms associated with towns like *R. rattus diardii* and *R. norvegicus*. Similarly, *R. exulans* caught in houses in Singapore are more heavily infected than those caught in wasteland on the mainland. The comparatively heavy infection of *R. r. diardii* by Acanthocephala is doubtless associated with the diet, these helminths being acquired by eating cockroaches, grubs, etc. The collection of worms is being continued so that the endoparasites of a representative sample of a wide variety of animals will be available for study. When these worms have been identified and their mode of transmission determined there should emerge an interesting ecological picture of the host-parasite relations with the environment and mode of life of the host.

Summary

Previous investigations of helminth infections in man and animals in Malaya are summarised up to date. In the case of human infections, the importance of hookworm was recognised very early, and great improvements in its control followed the findings of a Commission in 1915. Filariasis is known to be very severe locally and to extend even to Aborigines deep in the hinterland. Two species of *Mansonia* have been shown to transmit the infection. "Sawah-itch" is known to be caused by *Schistosoma spindale* and members of the "elvae" group. A number of studies of helminth infections of animals—e.g. "aortic worms", filariasis, onchocerciasis—are summarised. It is noteworthy that *Dirofilaria immitis* has been recovered from the orangutan.

Recent studies of helminths from animals collected by the Colonial Office Research Unit are described briefly and the results are provisionally tabulated. Investigations continue on these infections.

TABLE.—Infection of animals by major groups of helminths
(Interim tabulation).

Hosts.	Total number examined.	Total number infected.	Numbers infected with			
			Acantho- cephala.	Nema- toda.	Trema- toda.	Cestoda.
ARBOREAL ANIMALS.						
Squirrels						
<i>Callosciurus caniceps</i> ...	2	0	0	0	0	0
<i>C. notatus</i> ...	8	4	0	4	0	0
<i>C. nigrovittatus</i> ...	5	2	0	2	1	1
<i>C. tenuis</i> ...	2	2	0	2	0	0
Flying Squirrels ...	4	2	0	2	0	0
* <i>C. adamsi</i> ...	2	2	0	1	0	2
* <i>Nannosciurus whiteheadi</i> ...	2	0	0	0	0	0
Tree Rats.						
<i>Chiropodomys gliroides</i> ...	4	2	0	0	0	2
<i>Rattus canus</i> ...	6	2	0	2	0	0
<i>R. cremoriventer</i> ...	10	5	0	4	0	3
Tree shrews.						
<i>Tupaia glis</i> ...	4	2	0	2	1	0
<i>T. minor</i> ...	2	1	0	1	0	0
* <i>T. gracilis</i> ...	1	0	0	0	0	0
* <i>T. montana</i> ...	5	0	0	0	0	0
* <i>Dendrogale melanura</i> ...	1	0	0	0	0	0
Others.						
<i>Arctitis binturong</i> ...	1	1	0	1	0	0
<i>Nycticebus coucang</i> ...	2	0	0	0	0	0
Bats ...	3	1	0	1	0	0
Tree lizards ...	24	24	0	24	1	0
TERRESTRIAL ANIMALS.						
Squirrels						
<i>Rhinosciurus laticaudatus</i> ...	2	2	0	2	0	0
<i>Lariscus insignis</i> ...	1	0	0	0	0	0
* <i>Dremomys everetti</i> ...	9	2	1	0	0	2
Rats.						
<i>Rattus rattus jalorensis</i> —						
Wasteland... ..	32	16	0	15	0	8
Oil-Palm	42	18	2	14	0	4
<i>R. r. argentiventer</i> ...	23	21	0	16	0	12

* From North Borneo, 1952

TABLE.—Infection of animals by major groups of helminths—*cont.*

Hosts.	No. examined.	No. infected.	Acantho- cephala.	Nema- toda.	Trema- toda.	Cestoda
<i>R. exulans</i> —						
Wasteland...	17	3	2	2	0	1
*(Borneo) ...	22	7	0	6	0	2
<i>R. mülleri</i> ...	35	19	1	18	0	3
<i>R. bowersi</i> ...	12	6	0	5	0	1
<i>R. sabanus</i> ...	77	70	1	58	13	54
<i>R. whiteheadi</i> ...	19	10	0	7	1	3
<i>R. rajah</i> ...	17	8	0	7	1	5
* <i>R. alticola</i> ...	4	2	0	1	0	2
* <i>R. infraluteus</i> ...	2	2	0	1	1	2
Insectivores						
<i>Crocidura</i> sp. ...	2	1	0	0	0	1
* <i>Hylomys suillus</i> ...	4	2	0	2	0	0
<i>Echinosorex gymmurus</i> ...	2	0	0	0	0	0
Others						
<i>Sus scrofa</i> ...	3	2	0	2	0	1
<i>Tragulus kanchil</i> ...	2	1	0	1	0	0
<i>Felis bengalensis</i> ...	5	5	1	3	0	3
* <i>Helictis orientalis</i> ...	2	1	0	0	0	1
<i>Manis javanicus</i> ...	0	0	0	0	0	0
Ground birds ...	2	1	0	1	0	0
Skinks ...	1	0	0	0	0	0
Snakes ...	10	8	0	8	0	0
Frogs... ...	5	4	0	4	0	1
DOMESTIC SPECIES						
Rats						
<i>Rattus rattus diardii</i> ...	320	227	78	103	0	149
<i>R. exulans</i> —						
Kuala Lumpur ...	5	2	0	2	0	0
Singapore ...	128	72	5	67	0	13
<i>R. norvegicus</i> ...	180	169	4	144	0	148
<i>Mus musculus</i> ...	104	39	0	35	0	8
Others						
<i>Paradoxurus hermaphroditus</i> ...	3	0	0	0	0	0
Domestic cat ...	1	0	0	0	0	0

* From North Borneo, 1952

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MALAYSIAN PARASITES III

A SUMMARY REVIEW OF COLLECTIONS OF TROMBICULID MITES IN THE ASIATIC-PACIFIC AREA

By

J. R. AUDY

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Introduction

Although trombiculid mites are among the most numerous of all ectoparasites of mammals in the tropics of this region, relatively few were collected until after 1930. The great stimulus provided during World War II by researches into scrub-typhus has gradually given way to the stimulus provided by any large and newly amassed body of information in which there is widespread interest by a considerable number of fellow-workers.

These mites are well known because some members transmit scrub-typhus and others cause scrub-itch, an affliction which may have considerable economic and military importance locally and which is much more widespread than scrub-typhus. A number of workers are now suspecting that they may transmit various rickettsial, viral, and even protozoal (e. g. *Toxoplasma*, Giroud *et al.*, 1952) infections among their animal hosts*. They represent a rich and numerous source of potential vectors of the zootic infections which form the background to a number of human diseases.

Sufficient information about the trombiculids is now gathering for useful zoogeographical studies to be started. It is important for such purposes to distinguish between (a) casual collections from some occasional host or a few hosts, (b) extensive collections, by casually sampling a relatively large number of foci in a country or district and (c) intensive collections, carried out over a year or more. The known patchy distribution of these mites, and the fact that many or most of them show more or less seasonal incidence, means that all casual and most extensive collections are likely to give a false impression of the species present and their relative abundance. Furthermore, deforestation and settlement tend to eliminate most of the native species of host and mite, and to allow a minority to become locally very populous together with introduced mites and introduced commensal hosts, as may be seen in Table I. Collections made around villages and in cleared areas may thus leave the native mite fauna almost unsampled, even though the cleared areas may have become considerably overgrown.

* All the available epidemiological evidence also incriminates a species of *Trombicula* as the vector of Epidemic Haemorrhagic Fever (EHF) in Korea (Department of the Army Technical Bulletin TB MED 240, Washington, D.C., U.S.A., 5 May 1953, p. 5).

TABLE 1.

DISTRIBUTION OF SPECIES OF HOSTS AND MITES COLLECTED IN SELANGOR STATE, MALAYA
(cf. TABLE 1, AUDY & HARRISON, 1951).

Source.	Rodents and Insectivores.			Trombiculid Mites.	
	Number trapped (to 1951).	Number of Species.	Number of Genera.	Number of Species.	Number of Genera.
Forest	5,524	49	30	58	6
Deforested areas	3,459	15	8	16	5
Town (houses in Kuala Lumpur)...	6,813	5*	3	2(5†)*	2

* includes presumably introduced species. † the vectors *T. deliensis* and *T. akamushi* may be found exceptionally in the suburbs, so also may *T. wichmanni*, derived from poultry.

An attempt is made below to summarise the main sources of trombiculids in the Asiatic-Pacific area. There were only six considerable collections made before the War : by Tanaka, Nagayo and others in Japan, by Mehta in India, by Walch in Sumatra, by Lewthwaite and Gater (Institute for Medical Research) in Malaya, by Gunther in New Guinea, and by Heaslip, Womersley and others in Australia. These together with casual collections yielded some 76 species. Taking certain undescribed material into account, the total number of trombiculid mites (including leeuwenhoekine or leeuwenhoekiid mites) now known from this same theatre alone probably exceeds 350. The number of new species from this region described in each decade has been as follows, the names of the principal investigators concerned being shown in brackets. It will be seen that in the three decades before 1950 these mites were described at a rate of 4 or 5 new species per annum, while since then the annual rate has been about 40.

Before-1920	...	...	14 spp.	(Oudemans, Hirst).
1920-1929	...	...	20 spp.	(Oudemans, Walch, Nagayo <i>et al.</i>).
1930-1939	...	...	42 spp.	(Gater, Womersley).
1940-1949	...	...	75 spp.	(20 before 1945, 40 after) (Womersley, Heaslip, Gunther, Radford, Kohls, Philip, Wharton).
1950-1952	...	...	over 120	(Womersley, Wharton, Philip, Fuller Traub, Hardcastle, Radford, Audy)

During the War (a) McCulloch in particular made many collections in Australasia and Borneo ; (b) Wharton and other members of U.S. Navy Medical Research Units (NAMRU 2) collected and studied extensively in the Pacific, while Wharton and Hardcastle made an important intensive study of bird-chiggers of the genus *Neoschöngastia* ; (c) the U.S. Typhus Commission made very considerable collections in two theatres, viz. (i) in the Pacific area (New Guinea, Philippines) by Philip and Kohls in particular, who collaborated with Womersley over the taxonomic studies while they themselves were in the field, and (ii) in Assam, North Burma, and southwest China, by Fuller, Millspaugh, Sundermeyer, Melvin and Weber, who were based at Myitkyina, North Burma ; (d) Radford, followed by Jayewickreme, collected in Ceylon, while later, (e) Radford collected intensively in Addu Atoll (Maldives) and then for six months worked with (f) the Scrub Typhus Research Laboratory, a British War Office unit which made

an intensive collection in its base area at Imphal near the Indo-Burma border ; (g) Audy and Ash, two members of this laboratory, made an extensive collection in South Burma. The material from the Scrub Typhus Research Laboratory has been described by Radford and by Womersley and a general account is in press (Audy *et al.*, 1953).

In addition to these, a number of investigators in the Japanese Army of Occupation made sundry collections in the occupied countries. Investigations appear to have centred on the Nampogun Boekikyusui-Bu (Japanese Army Institute for Preventive Medicine) in Singapore under the direction of Lt.-Colonel Kiyoshi Hayakawa. The Institute issued a number of its own Bulletins in Japanese. After the reoccupation, Hayakawa wrote a report of the investigations in English and gave it to Colonel M. H. P. Sayers, O.B.E., who gave it to the present writer, who in turn arranged through the courtesy of Mr. W. H. Rigglesworth of the War Office to have a number of copies made and distributed. Copies were sent to Hayakawa in Japan, while his report was abstracted in the *Tropical Diseases Bulletin* (Hayakawa, 1946). Entries 15, 30, 31, 38, 39 and 57 in Table 2, relating to these collections, are abstracted from Hayakawa's report and the Bulletins quoted.

After the War, the work of the British Army Scrub Typhus Research Laboratory was continued by the Colonial Office Scrub Typhus Research Unit at the Institute for Medical Research, Kuala Lumpur. This unit was supported wholly by Colonial Development and Welfare funds from mid-1947 to the beginning of 1952, after which half the research expenditure has been borne by the Federation of Malaya. Apart from making an intensive collection in Malaya, this unit has received a very valuable extensive collection made in various parts of India by Lt.-Colonel S. Lal Kalra, who was formerly Pathologist in charge of the G.H.Q. (India) Field Typhus Research Team at the joint laboratory at Imphal. Considerable material from Hong Kong has also been received from Mr. J. D. Romer, and from Sarawak in collaboration with Mr. Tom Harrison, O.B.E., Government Ethnologist and Curator, Sarawak Museum. The unit at first undertook the task of a sorting-house while studying the bionomics of the ectoparasites of Malayan animals, and trombiculid mites were passed to Womersley who has incorporated the bulk of the material in his recent monograph. This unit has also had the privilege of collaborating with Lt.-Colonel Robert Traub of the U.S. Army Medical Research Units which have been based at the Institute for Medical Research from time to time since 1948. As part of this collaboration, two considerable collections have been made in North Borneo during the course of other investigations. Most of the material from the first expedition and some from the second is described in this *Study*. Preliminary checklists of the Malaysian trombiculids and leeuwenhoekids (then totalling 93 species of which 52 were hitherto undescribed) were published for reference in the Annual Report of the Institute for Medical Research for 1951. The total number is now nearly 130. The Malaysian collections have been reviewed above (Audy and Harrison, this *Study*, pp. 1-22).

Summary of Trombiculid Collections in the Asiatic-Pacific area (pages 36-41).

The Summary covers the noteworthy collections made in the area extending from east Asia to Australia and the Pacific islands, grouped as follows : *A*, India, Ceylon, Burma, and the adjacent parts of southwest China and Thailand ; *B*, Malaysia (Malaya, Sumatra, Borneo) plus the Celebes and Hong Kong ; *C*, Japan, Formosa ; *D*, Philippine Islands ; *E*, Australia, New Guinea, New Zealand, and all the islands in the western Pacific (except for Formosa, the Pescadores, and Japan). Entries are arranged within groups roughly in chronological order, but an effort has been made to impose some logical order as well. Wherever possible the number of mammalian, avian, and other hosts examined are shown. The number of species

of trombiculid mites are shown as (a) the total number recorded, with the number of these which were "new", i.e., *undescribed at the time of collection* (a number which of course must be taken with caution), (b) the number of these species in each of four generic groups, related respectively to *Trombicula* (filiform sensillae), *Schöngastia* (clubbed sensillae; including *Walchiella*), *Gahrlepiea* (the genus *sensu lato* after Womersley), and the Leeuwenhoekids (including *Hannemania*).

The names listed under the head of Responsible Investigators have as far as possible been restricted to those who were actually responsible for the investigation of the trombiculid mites, and not those colleagues who were responsible for the study of the animal hosts or the other parasites. The names have been placed in alphabetical order except where one of a pair of workers has borne particular responsibility for the investigation. Extracts of this table, compiled from published accounts, have been sent to many of the workers concerned for checking, and the writer is indebted to H. S. Fuller, C. E. M. Gunther, G. M. Kohls, R. N. McCulloch, C. B. Philip, R. V. Southcott, R. Traub, and H. Womersley for their help. In the case of the collections made by the China-Burma HQ of the U.S. Typhus Commission, and the extensive collections made by NAMRU 2, it was impossible to prepare a summary from published accounts. The writer is therefore particularly grateful to Traub for providing all the data for the former collection and to Wharton for all the data from the registers of NAMRU 2. Unfortunately no replies were received up to the time of going to press from the All-India Institute for Public Health in Calcutta so that their considerable collections in Bengal are here represented (entry 28) by the data given provisionally by Krishnan *et al.* (1949). The *T. muris* of that paper is here treated as *Euschöngastia indica*. The author directly responsible for the work with mites is not known to the present writer but he believes it was Dr. R. O. A. Smith. The writer has been in contact with Mr. M. G. Raja Varma, Research Fellow of the Indian Council of Medical Research, who has been working under Dr. Smith at the Bengal Typhus Enquiry. Entry No. 28A relates to work done between 1950-1952, the data being derived from correspondence with Mr. Raja Varma who has very kindly allowed the summary to be included in the Table.

The responsible organisation has been shown wherever the investigation concerned was part of its avowed policy. In spite of all efforts to be accurate, there will be discrepancies in and omissions from this table, to which the writer would appreciate having his attention drawn.

Except for the lumped entry (55) for Sasa and others, no mention is here made of the extensive collections recently made in Japan and Korea in connexion with studies of epidemic haemorrhagic fever (EHF).

Acknowledgement should be made to a number of collectors whose names do not appear in the tabular summary. Apologies are offered to those whose names are inadvertently omitted from the list of these contributors: S. L. Allman, R. H. Baker, T. O. Berge, J. M. Bonin, A. A. Bullock, R. C. Bushland, R. K. Carter, H. M. Cooper, W. D. Exton, W. D. Fitzwater, W. K. Ford, J. M. Fritts, C. J. Hackett, J. Hake, D. E. Howell, Major Hicks, D. Johnson, J. R. Kinghorn, G. H. McQueen, J. R. Mangram, I. M. Mackerras, M. J. Mackerras, F. J. Mitchell, A. Mundan, L. A. Posekany, K. N. A. Rao, T. M. Rivers, M. L. Roonwal, J. N. Strong, D. C. Swan, A. Rau, G. M. Rio. The following permanent institutions have sponsored a considerable amount of work on chiggers: South Australian Museum, Adelaide (Womersley), the Laboratory of Pathology and Microbiology at Cairns (D. J. W. Smith and formerly, E. H. Derrick) and at Brisbane (Heaslip), the Queensland Institute of Medical Research, Brisbane; the Institute for Medical Research, Kuala Lumpur; Kitasato Institute for Infectious Diseases, Tokyo; All-India Institute of Hygiene and Public Health, Calcutta; U.S. Army Medical Service Graduate School, Washington.

COMMENTS ON THE SUMMARISED COLLECTIONS

The relative poverty of deforested and settled areas.

This feature, clearly illustrated by the data in Table 1, is apparent in the following collections (the numbers in brackets refer to the numbers in the tabulation on pp.36-41):

Mehta (2) in North India, trapped "only in dwelling houses and shops, both in the urban and semi-rural areas" and obtained 5 species from 2,451 hosts.

Krishnan *et al.* (28) in the suburbs of Barrackpore and Calcutta obtained 9 species from 1,064 hosts. Their collecting area will have included open scrub.

Gater (33) obtained 7 species from some 600 rats from around Kuala Lumpur; but 24 species from the same number of hosts from the forest edge a few miles away.

Kalra (21-27) obtained only 3 species from 1,204 rats and shrews from the townships of Jubbalpore and Bangalore, but at least 18 species from 485 rats from North India.

Jayewickreme (17-20) and Radford (16) in Ceylon got only 3 species from 252 hosts in Colombo, only 7 from the well-cultivated area of Nalanda, and 11 from 338 hosts from the moderately cultivated area round Embilipitiya.

Nagayo and other workers in Japan (50), collecting thousands of voles in the restricted habitats of the infected fields in northwest Honshu obtained only 6 species, but four times this number have recently been obtained by collections (55) in a wider variety of habitats.

A special example of this effect is found in the fauna of islands of an oceanic type—3 species on Bat Island (84), 5 on Addu Atoll (33), 2 on Jarak (in 40), and 5-7 on islands such as Okinawa.

Gater's collection (33) of 7 species in Kuala Lumpur is particularly interesting as we would now find only 2 species in the town proper, and only some 4-5 species in its suburbs. Gater mentioned *Gahrliopia fletcheri* as being fairly common on the house-rats but it has now practically disappeared from the whole town area. These are reflections of the sophistication of the town during the intervening twenty years.

The effect of bias in collecting host species

Gunther (1940) reported that about 90 per cent. of some 2,000 chiggers collected by him in New Guinea were *Trombicula wichmanni* (reported as *T. minor*). *T. wichmanni* is essentially a bird-chigger, and he collected ten times as many birds as mammals. His findings contrast directly with those of Heaslip (1941) who reported that 90 per cent. of some 2,000 chiggers collected by him from mammals were *T. deliensis*.

The late Dr. Consett Davies (No. 79) by collecting only reptiles yielded records of 4 species of *Eutrombicula*. A similar bias, in favour of two related groups of *Schöngastia* and of *Trombicula* from reptiles, was evident in the studies made by Dr. R. F. Lawrence (1949) in South Africa. Dr. D. J. W. Smith (No. 64) appears to have collected 6 (new) species of *Euschöngastia*, but none of *Trombicula*, from mammals in Australia but the reason for this has not been discovered.

Boot-collections are well recognised as being biased.

Bird-chiggers and the vectors of scrub-typhus are particularly likely to be introduced to oceanic islands, and the species recovered by the investigator will be influenced greatly by the inclusion or exclusion of birds.

Effects of seasonal changes

Seasonal effects are not actually revealed by the tabular summary though they have been found by almost all the workers who have made intensive collections. In the Imphal area (1945-1946) larvae of the vector *T. deliensis* had a pronounced wet-season incidence. They were replaced by *Euschöngastia lanius* and the related *E. kohlsi* during the cold dry season (Audy 1947, 1949, Audy *et al.* 1953). Collections made in the same patch of scrub a few months apart gave completely different pictures of mite incidence.

Two batches of chiggers from an endemic area, Stonecutter's Island, Hong Kong, were sent to us by Mr. J. D. Romer. *T. deliensis* made up the bulk of the first batch while the second batch contained no *T. deliensis* but a number of chiggers of three species of *Euschöngastia* in the *lanius*-group (new subgenus Audy 1953, this *Study*, p. 152). This was so like the findings in Imphal that we were able to infer that the first collection was made during a wet hot period and the second during a cooler dry season (Table 2).

TABLE 2.

INFESTATION OF *Rattus rattus* SUB-SPECIES IN MANIPUR (IMPHAL), AND
HONG KONG (STONECUTTER'S ISLAND).

Place.	Mites per rat (approximately)		Rain- fall p.m. ins.	Temperature (means in °F)		No. of rats.	Period.
	<i>Trombicula deliensis</i> .	<i>Euschöngastia (lanius-group). spp.</i>		Max.	Min.		
Imphal ...	50	nil	12	85	72	over 200	July, 1945
Hong Kong ...	20	nil	15.6	87	81	8	Aug.-Sept., 1949
Imphal ...	0.5	30	nil	79	72	120	Jan., 1945
Hong Kong ...	nil	10	1.4	76	70	9	Jan.-Feb., 1950

Mohr (1947) carried out some very interesting studies in a transect across forest edge in New Guinea during dry weather. He found more *T. deliensis* on rats from the forest than on those from open scrub. In the light of our experience in Imphal and Malaya we would interpret this as a differential seasonal effect. The open scrub rapidly dries out while the forest floor remains damp, especially in ravines and gullies. The same effect was found in Imphal where 70-80 per cent. of rats caught in both open grassland and adjacent gallery forest during the height of the rains were infested by *T. deliensis*, while during the dry season the infestation dropped to below 0.5 per cent. in the scrub but to over 10 per cent. in the forest.

Distribution of the major groups of trombiculids.

Table 3 shows consolidated data for the countries summarised on p. 36ff., supplemented by data for countries outside this area. It is difficult to draw conclusions from such overall data but several general impressions emerge. The following tentative observations may be added to those of Wharton, aided by Fuller (1952). The number of Leeuwenhoekine species recorded is often a matter of special host selection, but Africa, the Americas, and Australia appear to have the most species. In Australia (and to a much lesser extent in New Guinea) we have a wealth of species of *Acomatacarus* on mammals and Australasia certainly appears to have been an active centre of evolution of this group. The African representatives include a number of species of *Acomatacarus* from reptiles and from a few mammals.

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The American representatives, totalling 30 leeuwenhoeikiines, include no less than 14 species of *Hannemania* from frogs, toads and salamanders. In spite of a bias in host selection by collectors, one may reasonably suspect that this may be a predominantly Old World genus. In the Oriental region (where batrachians have admittedly not been so extensively searched for chiggers) leeuwenhoeikiines are uncommon : they appear to be represented chiefly by *Whartonia* on bats (several species unpublished) and by various species mostly on reptiles and arthropods.

TABLE 3.

NUMBERS OF SPECIES OF TROMBICULIDS IN THE *Trombicula*, *Euschöngastia*, AND *Gahrlepiea* GENERIC GROUPS, AND OF LEEUWENHOEIKIINES IN THE MAJOR REGIONS OF THE WORLD.

		Species and percentage of total species.				
		Total number species.	<i>Trombicula</i> group.	<i>Euschöngastia</i> group.	<i>Gahrlepiea</i> .	Leeuwenhoe- kiines.
INDIA						
— less USATC coll.	...	63	34 54%	14 22%	14 22%	1 1%
— North Assam	...	23	5 22%	8 35%	9 39%	1 1%
BURMA, NORTH						
— Shingbwyiyang	...	39	8 20%	21 54%	9 23%	1 1%
— Myitkyina	...	64	28 44%	27 42%	11 17%	3 5%
MALAYSIA	...	129	49 38%	44 34%	29 22%	7 5%
NEW GUINEA	...	51	16 32%	28 56%	3 6%	4 8%
AUSTRALIA	...	64	17 27%	35 54%	0 0%	12 19%
JAPAN	...	26	21 21%	3 3%	2 2%	0 0%
EUROPE (incl. RUSSIA)	...	24	18 75%	4 17%	0 0%	2 8%
NORTH AMERICA	...	66	31 47%	20 30%	1 2%	14 21%
CENTRAL AMERICA & MEXICO	...	34	20 59%	7 20%	0 0%	7 20%
SOUTH AMERICA	...	44	24 55%	8 18%	18 41%	12 27%
AFRICA	...	92	36 39%	35 38%	1 2%*	20 22%
— SOUTH only	...	64	19 30%	26 41%	1 2%*	18 28%

* Since this paper was written, Vercammen-Grandjean has found more than 7 species of gahrlepiines in the Belgian Congo; 5 of these have been described; some of the species are intranasal (see this *Study*, p. 159).

The Gahrlepiines are clearly best developed in the Oriental region. A few species extend to New Guinea and Japan but gahrlepiines are rare in Australia (no species) and the Americas (1 species). They are rare in Africa (1 species) but the forests of Africa have hardly been explored yet and Vercammen (personal communication) has found distinctive gahrlepiines in a niche which has been universally neglected. All opinions on African gahrlepiines are therefore premature.

In the case of the Trombiculines, which appear to be biologically very "successful" it appears possible that those of the *Euschöngastia* group, with clubbed sensillae, are particularly well developed in the tropical forest belt, while species of *Trombicula* sensu lato appear to be ubiquitous but also to extend most successfully to higher altitudes and higher latitudes, exemplified by Japan with the ratio *Trombicula* &c. : *Euschöngastia* &c. at 21 : 3, Russia 7 : 0, Europe 12 : 4, Canada, 5 : 1. The ratio for India 34 : 14 is similar because of the large number of species of *Trombicula* from the collections from the mountains of Kashmir and Kumaon but it is reversed (*Euschöngastia* group dominant) in the collection (No. 9) from the forest of the Hukawng Valley in North Burma, and in New Guinea and Australia.

A TABULAR SUMMARY OF TROMBICULID COLLECTIONS IN THE ASIATIC-PACIFIC AREA

Responsible Organisation and Investigators.	COLLECTION.		HOSTS.			TROMBICULID MITES.			
	Locality.	Period.	Total mammal hosts examined.	Total birds.	Other hosts.	Total species chiggers ("new" in brackets).	Trombiculid Mites.		Sources of Information.
							<i>Trom-Schon-Gahr- bicula. gastia liepia. &c. &c.</i>	Leeu- wen- hoek- iids.	
A.—INDIA, CEYLON, BURMA, SOUTHWEST CHINA, THAILAND.									
1. HIRST, PAIVA ...	India, Calcutta ...	Jun., 1935-May, 1936	?2	0	0	3(3)	1	1	0 Hir 15
2. MEHTA ...	N. India, Simla Hills (Kasauli, Sabathu)	Jun., 1935-May, 1936	2,451	0	0	5(?1)	?3	1	0 Meh 37
Medical Research Council Scrub-Typhus Commission.									
3. RADFORD ...	Maldiva Is., Addu Atoll	Nov., 1944-Feb., 1945	528	0	Orthoptera	5(1)	2	2	0 I Rad 46a
Scrub Typhus Research Laboratory (Imphal), South East Asia Command.									
4. AUDY, COCKINGS, KALRA, T. J. LAWRENCE, RAD- FORD, FORD, THOMAS	India, Manipur (Imphal area)	Mar., 1945-Mar., 1946	2,073	53	Few snakes	35(26)	13	9	1 I Rad 46b, 52 Wom 52, Audy &c 47, 51, 53
5. BROWNING, KALRA ...	Burma, Mandalay (Fort) & Sagaing	July-Aug., 1945	57	—	—	—	—	—	— B & K 47
6. AUDY, ASH ...	South Burma(triangle Toungoo-Prome- Rangoon)	Oct.-Nov., 1945	212	0	0	11(4)	2	5	0 Aud &c 53
Army Pest Destruction Advisory Unit, Rangoon.									
7. HARRISON, DAVIS, R., MYO-KHIN	Burma, Rangoon ...	Nov.-Dec., 1945	87	0	0	5(0)	0	4	0 Aud &c 53
United States of America Typhus Commission, China-Burma Field Party, (Myitkyina).									
8. FULLER, MILLSPAUGH, MELVIN, SUNDERMEYER, TRAUB WEBER	North Assam, Ledo Area	Oct., 1944-Dec., 1945	402	0	0	23(19)	5	8	0 I Traub 49 & p.c., Tr & Ev 51
9. Do.	North Burma, Shing- buiyang	Do.	190	19	0	39(34)	8	21	0 I Tr p.c., Tr & E 51
10. Do.	North Burma, Myi- tkyina	Do.	814	241	4 rept.(-ve)	64(59)	28	27	0 I 3 Tr p.c., Tr & E 50ab

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11. FULLER, MILLSPAUGH ...	China, Yunnan, Kunning area and Kweiyang	August, 1945...	...	68	30	1 rept.	?	not worked out	Ful, Tr p.c.; Mil & F 47
12. Do.	China, Kweichow, Kweiyang area	Do.	...	80	36	0	?	not worked out	<i>ibid.</i>
Colonial Office Research Unit with Raffles Museum.									
13. AUDY, GIBSON-HILL ...	Nicobar Is., Car Nicobar	Oct., 1950	...	98	—	0	5(0)	2 3 0 0	Aud & H 53
U.S. Special Technical and Economic Mission to Thailand, in collaboration.									
14. ELBEL, TRAUB, AUDY, GOULD	Thailand, Bangkok area	—	...	140	0	0	11(4)	not worked out; continuing unpub.	
Japanese Army Institute of Preventive Medicine, Singapore.									
15. HAYAKAWA ...	Thailand, Kwe Noi Valley	June, 1943	...	200	0	0	4(0)	2 0 2 0	Hay 46
Medical Research Council. Scrub-Typhus Commission									
16. RADFORD ...	Ceylon, Colombo ...	April-October, 1944	...	228	0	0	3(0)	1 1 1 0	Rad 46b
Medical Department, Ceylon.									
17. JAYEWICKREME ...	South Ceylon, Embilipitiya	January-April, 1944	...	178	0	0	3(1)	1 1 1 0	J p.c., J 46, Wom 52
18. Do.	Do.	Oct., 1944-Jan., 1945...	...	338	0	0	11(3)	4 3 4 0	<i>ibid.</i>
19. Do.	Ceylon, Nalanda ...	May-August, 1944	...	368	0	0	7(3)	2 2 3 0	<i>ibid.</i>
20. Do.	Ceylon, Colombo (garden)	Aug., 1944-Aug., 1946	...	24	0	0	3(0)	2 0 1 0	<i>ibid.</i>
Army G. H. Q. (India) Field Typhus Research Detachment.									
21. KALRA, RAO ...	North India, Kumaon Hills	August-October, 1946	...	155	0	0	18(15)	13 2 3 0	Kal p.c., Wom 52 & I.M.R. unpub.
22. Do.	North India, Kashmir, Jammu, Ladakh	July, 1948-August, 1949 September, 1951	...	485	0	soil			<i>ibid.</i>
23. Do.	Central India, Jubbulpore town	Nov., 1946-April, 1947	...	536	0	0	not worked out completely		<i>ibid.</i>
24. Do.	Central India, Jubbulpore nr Jubbulpore (Seoni, Chindwara, and Singhori camps)	Nov.-Dec., 1946	...	404	0	soil	not worked out completely		<i>ibid.</i>
25. Do.	South India, Mysore suburbs	July, 1947	...	73	0	0	not worked out completely		<i>ibid.</i>
26. Do.	South India, Mysore, Bangalore	May-Sept., 1947	...	668	0	0	not worked out completely		<i>ibid.</i>
27. Do.	South India, Mysore, (Chedleth and Gudalur)	August, 1947	...	128	0	soil	not worked out completely		<i>ibid.</i>

p.c. = personal communication

A TABULAR SUMMARY OF TROMBICULID COLLECTIONS IN THE ASIATIC-PACIFIC AREA—(cont.)

Responsible Organisation and Investigators.	COLLECTION.		HOSTS.		TROMBICULID MITES.				
	Locality.	Period.	Total mammal hosts examined.	Total birds.	Other hosts.	Total species chiggers ("new" in brackets).	Trombiculid Mites.		Sources of Information.
							<i>Trom-Schon-Gahr- bicula. gasia liepia.</i> &c.	<i>Lecu- wen- hoek- ids.</i>	
A.—INDIA, CEYLON, BURMA, SOUTHWEST CHINA, THAILAND—(cont.)									
Bengal Typhus Enquiry, All-India Institute of Hygiene and Public Health, Calcutta.	India, Calcutta, (Barrackpore)	1947-1949	...	0	0	9(1)	5	2	0 Kri &c. 49
28. BOSE, GOSH, KRISHNAN, NEOGY, ROY, SMITH	India, Bengal, Barrackpore and Singur	May, 1950-May, 1952	1,040	0	0	11(6)	4	5	0 Var p.c.
B.—MALAYSIA AND HONG KONG.									
29. WALCH, KEUKENSCHRIJVER	North Sumatra, Deli (Medan area)	Oct., 1922-1925	... 812 & men	400	0	11(8)	6	4	1 0 Wal 22, 25, 27
Japanese Army Institute for Preventive Medicine, Singapore.									
30. HAYAKAWA	Sumatra, Atjeh and Medan	1945	...	200	0	3(0)	2	1	0 0 Hay 46
31. TAKEKAWA	Java, and Soekaboemi	1944	...	265	0	5(1)	2	2	1 0 Tak 45
Institute for Medical Research, Malaya, F.M.S.									
32. LEWTHWAITE, LESSLAR	Malaya, (K.L.)	Selangor 1927	...	130	0	5(0)	2	3	0 0 Fle &c. 28
33. GATER	Malaya, (K.L.)	Selangor 1929-1930 (17 months)	600	0	0	7(2)	4	2	1 0 Gat 32
34. Do.	Malaya, (Sungei Buloh)	Do.	600	0	0	24(17)	8	7	9 0 ibid
35. GUNTHER, RIO	North Borneo, Bode River	Sept., 1939	?	0	0	4(3)	2	1	1 0 Gun 40
36. MCCULLOCH	Borneo (Balikpapan, Brunei, Labuan)	May-Oct., 1945	?	0	boots	4(2)	1	2	1 0 Wom 52
37. Do.	Celebes, Halmahera	May, 1945	?	0	boots	4(2)	2	1	1 0 Wom 52
Japanese Army Institute for Preventive Medicine, Singapore.									
38. HAYAKAWA, ICHIKAWA, TANAKA, YOSHII	Malaya, esp. Johore, Layang Layang	Dec., 1943-May, 1945	ca. 8,000	0	0	7(0)	2	3	2 0 Hay 46; Hay &c. 44
39. HOKARI	Singapore, Sime Rd. Camp	June-July, 1944	...	91	0	3(0)	2	1	0 0 Hok 45

Colonial Office Scrub Typhus Research Unit, Institute for Medical Research, Malaya.

40. AUDY, NADCHATRAM, LEE
Malaya,
esp. Selangor

Dec., 1947-1952, Dec. 20,344 103 604 rept. Soil Arthropods 86(43) 34(22) 24(15) 24(6) 4 Aud & H 53, Aud 52, 53ab

Colonial Office Research Unit jointly with United States Army Medical Research Units in Malaya: also with Sarawak Museum, and Municipal Urban Council, Hong Kong.

41. TRAUB, AUDY ... North Borneo: July-Aug., 1951; May- June, 1952 55 insects rept. 36 4 nests } 35(22) 12 16 5 2 Tr & A 53ab, Tr & E 53; and unpub. Aud & H 53

42. AUDY, HARRISON, TRAUB Sarawak, mostly Kuching area 1950-1952 ... 712 0 6 6 2 0 unpub.

43. AUDY, ROMER ... Hong Kong 1949-1950 ... 40 0 rept. 9(4) 1 4 3 1 Aud & H 53; Wom. 52

United States Army Medical Research Units in Malaya.

44. PHILIP, TRAUB: (1st Field Unit) ... Malaya, Selangor ... March-August, 1948... 450 18 0 ?(3) not worked out Tr. pc.; P and T 50

45. (2nd Field Unit) ... Do. do.... Nov., 1948-April, 1949 250 1 13 rept. not worked out *ibid.*

46. (3rd Field Unit) ... Do. do. Feb.-July, 1950 ... 550 6 12 rept. not worked out *ibid.*

47. (4th Field Unit) ... Do. do. June-Nov., 1951 ... 362 6 4 rept. not worked out *ibid.*

48. TRAUB ... Malaya, Pahang July, 1948 ... 33 1 0 not worked out *ibid.*

49. TRAUB, TIPTON ... Malaya, Pahang, March, 1950 ... 22 1 0 not worked out *ibid.*

C.—JAPAN AND FORMOSA.

50. TANAKA, NAGAYO, KAWAMURA, TAMAYA &c. N. W. Honshu ... 1905-1936 ... ? 412 soil 6(6) 6 0 0 0 Tan 16, 18; Kaw 26; N &c. 20ab, 21

51. HATORI, KAWAMURA, YAMAGAWA, SUGIMOTO Formosa and Pescadores 1913-1939 ... ? ? 6-7(2) 45 1 0 0 Hat 20; K & Y 21; 538

U.S.A. Typhus Commission, Pacific.

52. PHILIP ... N. W. Honshu, October, 1946... 10 0 0 4(1) 3 0 1 0 Ph. 47

53. Do. ... N. W. Honshu, October, 1946 ... 7 0 0 5(1) 4 0 1 0 Ph. 47

54. Do. ... Honshu, Mt. Fuji ... October, 1948 ... ? 0 0 6(1) 6 0 0 0 Kuw, B & Ph 51

55. SASA, FUKUZUMI, OBATA... Japan ... 1937-1952 ... ? ? ca 26(20) 21 3 2 0 0 S & c; Fuk p.c.

p.c. = personal communication

A TABULAR SUMMARY OF TROMBICULID COLLECTIONS IN THE ASIATIC-PACIFIC AREA—(cont.)

Responsible Organisation and Investigators.	COLLECTION.		HOSTS.		TROMBICULID MITES.						
	Locality.	Period.	Total mammal hosts examined.	Total birds.	Other hosts.	Total species chiggers ("new" in brackets).	Sources of Information.				
							<i>Trom- Schon- Gahr- bicula. gastia liepia.</i> &c. &c.	Leeu- wen- hock- iids.			
D.—PHILIPPINES.											
56. MOHR ...	Luzon, Lingayan, (Dagupin)	Jan.-April, 1944	?	?	?	4(1)	2	2	0	0	M 47
Japanese Army Institute for Preventive Medicine, Singapore.											
57. MURO, HAYAKAWA ...	Luzon	... August, 1944	?	0	0	1(0)	1	0	0	0	H & N 45
U.S.A. Typhus Commission, Pacific H.Q.											
58. PHILIP, WOODWARD ...	Luzon	... May-August, 1945	50	0	0	5(0)	5	1	0	0	P & W 46
59. Do. ...	Mindoro	... May, 1945	100	0	0	8(3)	6	2	0	0	Do.
60. Do. ...	Samar	... May, 1945	12	0	0	2(0)	2	0	0	0	Do.
61. Do. ...	Negros	... June, 1945	7	0	0	4(0)	4	0	0	0	Do.
E.—AUSTRALIA, NEW GUINEA, AND SOUTH-WEST PACIFIC.											
62. HIRST ...	Australia	... 192-19	?	?	?	5(5)	0	3	0	2	H 25, 26, 29, Wom. 52
South Australian Museum.											
63. WOMERSLEY ...	Australia	... —	?	?	?	10(7)	4	4	2	?	Wom. 52, p.c.
64. SMITH ...	Australia, land	Queens- mostly 1938	?	?	?	6(6)	0	6	0	0	Wom. 52
65. MCCULLOCH ...	Australia, esp. Queensland	1943-1945	?	birds	host soil	14(11)	2	8	0	4	Wom. 52; Mc. 44, p.c.
66. Do. ...	Celebes, Halmahera	May, 1945	?	?	hosts	4	2	1	1	0	Do.
67. HEASLIP ...	Australia, land	Queens- 1939	200	?	?	17(13)	3	12	0	2	H. 41; Wom. & H. 43
68. GILL ...	Do.	... November, 1944	?	?	?	4(4)	2	2	0	?	G &c. 45
69. SOUTHCOOT ...	Australia, Victoria	S. A., 1933-1941	?	?	rept soil	3(?)	0	0	0	3	5 p.c.; Wom. 52
70. Do. ...	Australia, and Tas- mania	1946-1952	?	?	rept soil	3(?)	0	0	0	3	Do.
71. Do. ...	Australia, N.T. only	Mar., 1942-June, 1942	52	4	56 rept soil	10(8)	5	4	0	1	Do.
72. Do. ...	Australia, land	Queens- July, 1943-Nov., 1944	15 18 men	30	85 liz. ca30 boots ca 150 soil	3(2)	Largely unworked				S p.c.
73. Do. ...	New Guinea, Aitape- Wewak	Nov., 1944-Feb., 1945	4	1	14 liz. 20 boots	?	unworked				S p.c.

74. MISCELL. COLLECTORS ...	New Guinea and Australia	1938-1947	...	...	+	+	20(r18)	6	13	0	1	Wom 52
75. GUNTHER ...	New Guinea	1939	...	ca 450	4,570	?	14(12)	2	10	1	1	Gun 39
76. Do. ...	Do.	1940	...	58	ca 15	0	12(4)	3	8	1	0	Gun p.c.
77. Do. ...	Do.	1941	...	call	ca 24	0	9(2)	2	6	0	1	Gun p.c.
78. MCCULLOCH ...	Do.	Jan., 1943-Aug., 1944	...	?	?	boots	12(6)	4	8	0	0	Wom 52, Mc p.c.
79. DAVIES ...	Do.	July-September	...	?	?	?	4(3)	4	0	0	0	Wom 52
U.S.A. Typhus Commission (Pacific Headquarters).												
80. KOHLS, PHILIP ...	New Guinea, Dobodura area	Oct., 1943-Oct., 1944	...	611	76	6 reptiles 133 boots soil	20(6)	5	11	2	2	Bla &c 45; K &c 45; P & K 45; P & K
81. KOHLS ...	New Guinea, Goodenough Is.	January, 1944	...	1	0	2 liz.	5(1)	3	2	0	0	Do.
82. KOHLS, PHILIP ...	New Guinea, Owi and Biak Is. (Schouten Gp.)	July-August, 1944	...	25	0	5 boots 9 boots	7(2)	4	3	0	0	Do.
83. KOHLS, PHILIP ...	New Guinea, Sansapor area	August, 1944	...	16	0	1 liz.	6(1)	3	2	1	0	Do.
84. PHILIP, KOHLS ...	New Guinea, Bat I (Purdy Group)	June, 1944	...	56	3	3 boots 5 boots	3(1)	1	2	0	0	K et al 45; P & C P & K 45
85. PHILIP ...	New Guinea, Hollandia	Nov.-Dec., 1944	...	ca 28	0	3 liz.	6(2)	4	1	0	1	P 47
86. GRIFFITHS ...	New Guinea, Sansapor area	August-Oct., 1944	...	64	0	soil	7(?)	2	4	1	0	G 45, 47
87. MOHR ...	New Guinea	Oct.-Dec., 1944	...	100	0	0	9(1)	1	6	1	0	Mohr 1947
United States Naval Medical Research Unit 2.												
88. WHARTON ...	New Caledonia	June, 1944	...	17	—	1 rept	0	0	0	0	0	Wh p.s.
89. Do. ...	New Hebrides	June, 1944-Jan., 1945	...	43	4	7 soil	0	0	0	0	0	Do.
90. Do. ...	Guadalcanal	June, 1944-Jan., 1945	...	7	17	11 rept	3	2	0	0	1	Do.
91. Do. ...	Bougainville	June, 1944-Jan., 1945	...	115	32	22 soil 51 rept 38 soil 8 arth	11(5)	4	6	0	1	Do.
92. Do. ...	Admiralty Is.	Aug., 1944-Feb., 1945	...	5	4	2 rept 5 soil	1	1	0	0	0	Do.
93. Do. ...	Philippines, Samar	Feb., 1945-March, 1945	...	35	6	3 boots 3 rept 25 soil	3(1)	2	1	0	0	Do.
94. Do. ...	Australia	November, 1944	...	1	—	5 soil	1	1	0	0	0	Do.
95. Do. ...	New Guinea	December, 1944	...	0	—	2 soil	1	1	0	0	0	Do.
96. Do. ...	Iwo Jima	March, 1945	...	1	2	soil	1(1)	0	1	0	0	Do.
97. Do. ...	Mariana Is...	Mar., 1945-Nov., 1945	...	236	238	16 rept 104 soil 2 arth	11(8)	7	4	0	0	Do.
98. Do. ...	Okinawa	April, 1945-Sept., 1945	...	53	61	50 soil 4 arth	7(7)	0	7	0	0	Do.
99. Do. ...	Caroline Is.	Aug., 1945-Nov., 1945	...	63	61	3 rept 18 soil	5(5)	0	6	0	0	Do.
100. Do. ...	Palau	Aug., 1945-Sept., 1945	...	58	166	2 rept 29 soil 1 boot	6(3)	1	5	0	0	Do.
101. DUMBLETON ...	Solomon Is. and New Zealand	1912-1944	...	?	?	6(4)	4	1	0	0	1	D 47

p.cs. = personal communication

Summary.

It is important for the zoogeographer to know how completely various localities have been sampled, and to be able to assess and compare casual, extensive, and intensive collections. The tabular summary here presented attempts to give this information for all noteworthy collections of trombiculid mites in the Asiatic-Pacific area.

Comments are offered on the effects of (a) bias in collecting host-species or in particular habitats, (b) deforestation, which impoverishes the fauna, and (c) seasonal changes. Tentative notes are made on the world distribution of generic groups.

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MALAYSIAN PARASITES IV

SPECIES OF *TROMBICULA* (ACARINA TROMBICULIDAE) FROM BORNEO

By

ROBERT TRAUB AND J. R. AUDY

Recent collections in Borneo

Three major collections have recently been made of animal hosts and parasites in Sarawak and North Borneo as part of the investigation of reservoirs and vectors of disease (entries 41 and 42 in the synoptic summary by Audy, 1953, this *Study*, p. 37). In 1950, collaboration was arranged between the Colonial Office Research Unit and Mr. Tom Harrisson, Government Ethnologist and Curator of the Sarawak Museum. Between May and July, Messrs. M. Nadchatram (working on parasites) and Ben Ensoll (collector of animals) of the above unit, and Mr. Johan bin Haji Adam, then of the U.S. Army Medical Research Unit, went to Sarawak to initiate the collection, the two latter accompanying Mr. Harrisson on an expedition to the interior, while Mr. Nadchatram started the base work in the Kuching area. The collection from the Kuching area has since been directed by Mr. Harrisson, using funds from the Colonial Development and Welfare Research Scheme which is operated by the Colonial Office Unit. Regular collecting in Sarawak ceased in 1952, a total of 712 animals having been collected with their parasites.

Two collections have since been made in British North Borneo by joint U.S. Army and Colonial Office Unit research teams during the course of studies on noxious animals and infections involving animal reservoirs. These investigations were made possible through the financial support of the Research and Development Board, Office of the Surgeon General, U.S. Army. The collections were as follows (see Map on p. 61):

1951 (July-August) : Mostly on Mt. Kinabalu between 4,000 and 10,000 feet altitude, from a base at the Tenompok Pass (ca. 4,500 ft.) above the village of Bundu Tuhan. A subsidiary collection was made at Menggatal Estate, west coastal plain near Jesselton.

1952 (May-June) : From the above areas and in addition from the forest reserve at Beaufort (foothills of west coastal plain south of Jesselton and opposite Labuan) and near the village Kabajang (swamp forest) on the Padas river between Beaufort and the sea. On this occasion, a number of trombiculid mites were bred to the nymph by Messrs. Nadchatram and Lee Fatt-Hing.

Descriptions of species of *Trombicula*

In the following descriptions, species described in detail are as far as possible used as standards of comparison for shorter descriptions of related species. A diagnostic chart is added. The palpal setation is indicated by the synoptic "palpal formula" (Audy, 1952), e.g. N/N/BbP signifying that the femoral, genual, and dorsal-lateral-ventral tibial setae respectively are nude (N) obviously branched or barbed (B), inconspicuously barbed (b), or feathery, plumose (P). Accession numbers of type material are shown as for the U. S. Army Medical Research Unit (A.M.R.U.), the Colonial Office Research Unit (C.O.R.U.), and the U.S. National Museum (U.S.N.M.). The terminology of the sensory leg setae is that of Wharton (1948) with the exception that in conformity with the names for the setae on segments other than the tarsus, the tarsal "spur" and accompanying "microspur" are here called the "tarsala" and "microtarsala" (as suggested by Audy, *loc. cit.*).

Trombicula flagellifera n. sp. (figs. 1-8, pp. 52, 53).

Diagnosis of Larva.—Immediately separable from all known Asiatic species in the genus by the presence of four very long whip-like setae on the hind legs, of which the mastifemorala is usually well over 105μ in length, ranging as high as 160μ .

Description of Larva.—*Body:* Subovate, about 282μ long (including mouth-parts) by 176μ broad in fairly engorged specimen. Eyes $2+2$, anteriormost circular, about $11 \times 11\mu$, posterior eye subovate about $10.5 \times 9.6\mu$. *Gnathosome:* Chelicerae about $2\frac{1}{2}$ times as long (13μ) as broad at base (5μ); each with a small subterminal tooth and a distinct, more proximal, ventral tooth or nubbin. Palpal coxae and femora punctate. Palpal formula N/N/NNN (i.e., all setae nude); palpal tarsus with a basal striated rod and about 5 bristles, 4 of these heavily plumose, one (subapical) apparently nude. Palpal claw 3-pronged; axial prong slightly curved, stout; dorsal straight, slender, inconspicuous; dorsoventral straight, short and fairly stout. Galeal seta N (i.e. nude). *Scutum:* Punctate; roughly rectangular; dimensions $47 \times 83\mu$; lateral margins almost straight and parallel; anterior margin slightly concave; shoulders at AL rounded; posterior margin sinuate, producing 3 shallow sinuses. Scutal setae with short barbs; similar to dorsal setae in size and shape; PLs inserted at angles slightly posterior to level of SBs; PL longer than AL. Sensillae long, about $68-90\mu$, virtually nude, tapering occasionally with a subapical branchlet. *Body Setae:* Dorsal setae similar to scutal setae; about 28-32, counting marginals arranged 2.8.6.6.4.2. One pair of plumose or subpectinate sternal setae between bases of coxae I and another pair between coxae III. True ventral setae about 36μ , subpectinate or plumose, about 8-12 plus 8 postanal caudal setae. *Legs:* All 7-jointed, coxae and legs punctate. All coxae unisetose; on first two coxae the seta is submarginal, near posterolateral angle; on coxa III the seta is median, at level of anterior fourth of segment. Non-sensory setae with unusually long, delicate but well-separated plumes or barbules. Sensory setae as follows Leg I: 2 genualae and microgenuala; 2 stout tibialae (1 subapical) and a microtibiala; a blunt striate tarsala ("spur" of Wharton) and a microtarsala (microspur) distal and slightly posterior, subterminala stout, with parasubterminala one-half its length, pretarsala well-developed. Leg II: a genuala; 2 well-developed tibialae in tandem, a blunt striate tarsala with anterior microtarsala, a pretarsala. Leg III: a conspicuous mastifemorala about $110-160\mu$ long; a mastigenuala about $95-110\mu$ and a normal genuala; a mastitibiala of about $60-90\mu$ immediately distal to a tibiala; with a nude or sparsely plumed subproximal mastitarsala, about 45μ long; flagellate setae are apparently easily broken or lost in the preserving or mounting processess, if not in life. Their bases may show a few delicate ciliations or barbules.

Type Material.—Holotype (C.O.R.U. 20948) ex *Crocidura*, a shrew, North Borneo, Mt. Kinabalu, Tenompok, elev. 4,500 ft., 16. vii. 1951 (R. Traub and J. R. Audy for U.S. Army and Colonial Office Research Units). 29 larval paratypes loc. cit. but as follows: 2 ex *Nannosciurus whiteheadi*, a pigmy tuft-eared squirrel; 19 ex *Hylomys suillus* (Erinaceidae), a "short-tailed shrew", vii. 1951 (R. Traub and J. R. Audy) and 19 ex *Hylomys suillus* 27. v. 1952 (J. R. Audy). Holotype (U.S.N.M. 2101) deposited in U.S. National Museum; paratypes in collections of the British Museum, South Australian Museum; Rocky Mountain Laboratory, Hamilton, Montana; in other institutions and in the authors' collections.

STANDARD MEASUREMENTS IN MICRONS, *T. flagellifera* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype ...	72	77	26	31	12	33	52	55	67	60	$\frac{77}{70}$ =1.1	$\frac{77}{43}$ =1.8	$\frac{77}{31}$ =2.47	$\frac{77}{33}$ =2.3
Paratypes (29) Mean	72	79	26	31	12	31	54	52	68	60	1.12	1.8	2.52	2.4
Range (+ or -) ...	3	4	1	3	1	2	4	4	4	3	0.05	0.1	0.08	0.03

Trombicula tuhana n. sp. (figs. 9-16, pp. 54, 55).

Diagnosis of Larva.—Near *T. flagellifera* n. sp. especially in that palpal setae are nude and in that Leg III bears fairly long sensory setae, including a mastifemorala. Readily separable in the absence of long whiplike setae on Leg III, the mastifemorala about 47μ long, not over 100μ . Further distinguishable in that the scutum is smaller and relatively narrower, i.e., PW about 65, not 78; ASB about 21, not 31 and ratio of PW/ASB is approximately 3.1, not 2.55; sensillary bases virtually in line with PL, not definitely at an anterior level. Galeal seta branched.

Description of Larva.—*Body:* About 258 by 203μ in partially engorged specimen. Anterior eye (9μ) somewhat larger than posterior eye (8μ), each subovate to circular. *Gnathosome:* Chelicerae about three times as long as broad at base. *Scutum:* Subrectangular, slightly less than half as long as broad ($32 \times 67\mu$)

Anterior margin sinuate, convex at shoulders and midpoint; lateral margins shallowly concave; posterior margin slightly biconvex, medially indented. Sensillary bases almost in a line with PL, but actually very slightly anterior to them. Sensillae nude for most of their length but subapically somewhat frayed; about 62μ long. AL setae about $3/5$ length of PLs; both pairs with barbs closely appressed to axis, barbs inconspicuous, particularly in PLs. *Body Setae*: Similar to scutal setae in size, shape and high degree of appression of barbs. Dorsal setae about 30, counting terminals, arranged 2. 8. 6. 6. the rest irregular. True ventral setae (about 33μ) plumose, fairly long, about 8 in number plus about 8 caudal setae, similar to dorsals but about $36-38\mu$ long. Non-sensory setae of legs with thin barbs, often appressed, not long and thin as in *T. flagellifera* n. sp. *Legs*: Sensory setae as follows: Leg I and II as in *flagellifera*. Leg III with mastifemorala on telofemur actually somewhat frayed proximally, about 48μ long or about as long as tibia; a mastigenuala (almost nude seta about 35μ) with an adjacent seta about one-half its length, tibia with 2 nude setae.

STANDARD MEASUREMENTS IN MICRONS, *T. tuhana* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype 28540 ...	61	66	26	22	10	24	29	33	56	50	$\frac{66}{57}$ =1.16	$\frac{68}{32}$ =2.0	$\frac{66}{22}$ =3.0	$\frac{66}{24}$ =2.75
Paratypes (7) Mean	59	65	26	21	10	23	31	33	55	49	1.20	2.1	3.07	2.8
Range (+or-) ...	2	3	1	2	1	2	3	3	4	3	0.05	0.07	0.08	0.07

Type Material: Holotype (C.O.R.U. 28540) and 13 paratypes ex *Nannosciurus whiteheadi*, the pygmy tufted squirrel, Mt. Kinabalu, Bundu Tuhan, elev. approx. 4000 ft., 7. vi. 1952 (J. R. Audy). Holotype (U.S.N.M. 2012) in U.S. National Museum, paratypes in British Museum and authors' collections.

Trombicula vorca n. sp. (figs. 17-24, pp. 56, 57).

Diagnosis of Larva.—Immediately separable from most *Trombicula* by the following combination of characters : a large conspicuous sclerotized or deeply pigmented anterior eye, which is relatively far removed from the scutum, posterior eye virtually inapparent or vestigial, and a palpal formula B/B/NNb. Agrees with *T. corvi* Hatori, 1920, in apparently possessing but a single large eye and with stout heavily barbed setae on palpal femur and genu, but readily separable as follows (taking the features of *T. corvi* after Womersley, 1952) : Sensillae apically frayed, proximally nude, instead of vice versa ; scutum submedially not "backwardly" curved ; with only about 70 dorsal setae, not over 100 ; with a humeral row of 6 or 8 dorsal bristles, followed by a row of 10 or 12, instead of a setal formula commencing 12.10.16 ; ventral palpal tibial bristle sparsely branched or frayed, not nude.

Description of Larva.—Engorged specimens huge, subquadrate, about $1135 \times 875\mu$ when mounted. Eyes pigmented, spherical, removed from scutum a distance equal to own diameter (22μ when measured at level when scutum is in focus); large anterior eye heavily chitinated, at a level slightly behind that of ALs; posterior eye represented but by a dim ovate vestige beyond sclerotized plate of anterior eye; an occasional specimen with a suggestion of an ocular plate about posterior eye. *Gnathosome*: Chelicers with subapical notch on inner surface. Galeal seta nude. Palpae with seta on femur and genu stout, heavily barbed or subpectinate; dorsal and lateral tibial setae stout, nude; ventral tibial bristle subapically frayed or ciliated. Palpal claw trifurcate. *Scutum*: Subrectangular; somewhat less than twice as broad as long; lateral margins almost parallel; anterior margin very slightly concave and with virtually no "shoulders" at insertions of ALs, which are not contiguous with margin; posterior margin somewhat convex opposite level of sensillae bases, elsewhere slightly concave; scutal setae with many short barbs; PLs the longest. Sensillae with branches commencing just at midpoint and extending to apex.

STANDARD MEASUREMENTS IN MICRONS, *T. vorca* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype ...	80	92	29	40	17	40	65	59	80	64	$\frac{92}{75}$ =1.23	$\frac{92}{57}$ =1.6	$\frac{92}{40}$ =2.3	$\frac{92}{40}$ =2.3
Paratypes (4) Mean	82	93	28	40	17	42	66	59	78	62	1.20	1.6	2.3	2.2
Range ...	3	4	—	3	2	2	3	3	4	5	0.05	0.05	0.03	0.08

Body Setae: With about 52-72 dorsal setae apparently arranged 6(8). 10. 12. the rest irregular; similar to PLs. With about 14-18 caudal (postanal ventral) setae, circa 60μ , resembling DS. True ventral setae about 58 in number progressively ranging from $36-55\mu$, approaching postanals. *Legs*: Sensory setae as follows: Leg I with two genuala and a microgenuala; with two approximated tibialae and

an adjacent microtibiala; tarsus with a well-developed tarsala, a distal microtarsala, a subterminala and a parasubterminala and a pretarsala. Leg II, a genuala; two tibialae; a tarsala and proximal microtarsala, a pretarsala. Leg III, a genuala and a tibiala.

Type Material.—Holotype and 5 paratypes from an unidentified bird, Mt Kinabalu, Tenompok, elev. 4500 ft., I. viii. 1951 (R. Traub). Holotype and paratype in U.S. National Museum (U.S.N.M. 2013); one paratype in collection of senior author, remainder in coll. of Colonial Office Medical Research Unit.

Comment.—A series of *Trombicula* from crow-pheasant collected at Beaufort, N. Borneo, iii. 1952 (*M. Nadchatram*) superficially closely resembles *T. vorca* n. sp. As can be seen from the following standard measurement, the scutum is definitely and significantly smaller, as are the scutal-bristles:

			AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Mean	...	...	69	80	28	32	12	35	50	52	64	52	1.2	1.2	2.2	2.35
Range	...	...	2	3	2	2	1	2	4	3	5	4	0.04	0.05	0.07	0.05

The posterior eyes in the Beaufort specimens are fairly well developed and on an ocular plate with the very large anterior eyes. In the smaller scutal measurements the Beaufort series are close to *T. ?densipiliata*, Womersley 1952, from the Celebes and the Solomons. Mr. Womersley has very kindly lent two specimens of his *?densipiliata*, but has been unable to locate *T. nissani* Dumbleton 1947. There is no doubt that *T. densipiliata* Walch, *T. ?densipiliata*, Womersley, *T. nissani*, *T. vorca* n. sp., and the form under study from Beaufort are all closely related. The results of further studies will be published later.

A number of nymphs of the Beaufort species or variety were bred by Mr. Nadchatram. These nymphs, to be described later, are very distinctive, with exaggerated humeral and posterior dorsal body-setae. They are close to *T. (Neotrombicula) canestrinii* (Buffa, 1899), described from adults from soil in Italy.

***Trombicula (Leptotrombidium) baluensis* n. sp. (figs. 25-33, pp. 58, 59).**

Diagnosis of Larva.—Unusual among chiggers of Southeast Asia in that the dorsal setae are very heavily barbed with thickened blade-like processes thus resembling species characteristic of Japan and Korea. Near *T. intermedia* Nagayo *et al.* (fig. 38-41, p. 60), and *scutellaris* Nagayo *et al.* (fig. 34-37, p. 60) of Japan, but immediately separable by virtue of the fact that in the new species the barbs of the dorsal bristles are less dense, far fewer in number per shaft and spaced further apart, i.e., the distance between barbs often 4-5 times their diameter at base instead of being almost contiguous; the barbs are much longer than in the Japanese forms, i.e. twice the diameter of the shaft or greater, blade-like, the seta appearing subpectinate or with teeth like a rake instead of the barbs being subequal to the diameter of the shaft. Further distinguishable from *T. (L.) intermedia* by the line of SB lying anterior to PLs instead of behind it as in *intermedia*—the difference expressed by A-P of about 30 instead of 24, or the ratio $PW/A-P$ being $77/30=2.6$ not $78/24=3.2$. *T. baluensis* is characterized by a relatively narrow AW—about 60, instead of 69-73 in *T. scutellaris* and *T. intermedia*.

Description of Larva.—*Body*: ovate in unengorged specimen, about $220 \times 150 \mu$. Ocular plate virtually contiguous with scutum, PLs in line with junction of anterior and posterior eyes. *Gnathosome*: Palpal formula $N(long)/N/NN.B(ca. 7)$. Palpal claw apparently bifid, with lateral prong straight and dorsomedial prong smaller, often recurved under lateral. Galeal seta B (*ca.* 8, fairly long). *Scutum*: About $40 \times 80 \mu$; trapezoidal except for slightly concave sinuate margin, and rounded PL corners; posterior margin slightly convex but flattened medially. AL and PL setae stoutly and densely branched, the proximal 6-8 branches, blade-like; the apical ones more appressed, appearing scale-like. AM seta proximally with rows of 6-7 short, stout barbules, apically the setules more slender. AM seta inserted on a non-punctate depressed area with lateral margins marked by a longitudinal, somewhat angled ridge; rest of scutum punctate except for another smooth area behind each SB. Sensillae about $45-50 \mu$ long; shaft proximally smooth; apical half with about 14 relatively conspicuous branches.

STUD. INST. MED. RES.

STANDARD MEASUREMENTS IN MICRONS, *T. baluensis* n. sp.

		AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype ...	...	64	78	35	27	15	30	55	53	62	59	$\frac{78}{60}$ =1.3	$\frac{78}{42}$ =1.9	$\frac{78}{27}$ =2.9	$\frac{78}{30}$ =2.6
Paratypes (8) Mean		63	79	35	28	15	30	54	54	61	59	1.28	1.85	2.8	2.6
Range (+ or -)	...	2	3	1	2	1	2	3	4	3	4	0.05	0.07	0.1	0.05

Body Setae: Dorsal setae about 40-55, including lateromarginals, frequently arranged 2. 10. 10. 10. 8... the rest confused; anteriormost about 55-61 μ long. Dorsal setae of characteristic appearance, with a stout shaft and 5-8 conspicuous widely separated blade-like barbs, with a few closely appressed scale-like barbules along length of shaft. True ventral setae ca. 25-30 μ long with many slender branches and no blade-like processes, about 22 in number, plus 4-8 caudal setae (postanal), somewhat longer with fewer branches and mostly with a few blade-like processes. **Legs:** Sensory setae as in *akamushi* group, i.e., Leg I with 2 genuala and a microgenuala; with 2 tibialae (one stout) and a microtibiala; with a blunt striate tarsala (spur), a microtarsala posterior and slightly distal to it, a well-developed subterminala and parasubterminala one-half its length, a pretarsala. Leg II with a genuala; 2 tibialae, one of which is stout and subapical; a tarsala and anterior microtarsala, a well-developed subterminala. Leg III with a genuala and a tibiala.

Type Material.—Holotype (C.O.R.U. 20946), and 2 paratypes ex *Crocidura*, a true shrew, Mt. Kinabalu, Tenompok, elev. 4500 ft., 17. vii. 1951. (R. Traub and J. R. Audy). Nine paratypes, *ibid*, but ex *Hylomys suillus* the lesser gymnura or short-tailed shrew, and one paratype ex *Dremomys everetti*, a ground squirrel. Four additional paratypes ex 2 *Hylomys* and one from *Rattus* sp., loc. cit., v. 1952 (J. R. Audy). Holotype (U.S.N.M. 2014); paratypes distributed as for *T. flagellifera* n. sp.

Trombicula (Leptotrombidium) pipellae n. sp. (figs. 46-53, pp. 62, 63).

Diagnosis of Larva.—Close to *T. (L.) longiseta* Womersley, 1952 and *T. deliensis*, Walch, 1922. Separable from all other known species of 'akamushi group' except *longiseta* by the relatively enormous length of the posterolateral setae (over 120 μ , cf. maximum of 85 in *deliensis*—the PLs are nearly 2½ times as long as ASB+PSB) and by the very long dorsal setae (a mean of over 85 μ , cf. a maximum of 67 in *deliensis*); AM also much longer (an average of 87, not 56 as in *T. longiseta*), but AL nevertheless of same approximate length (56 μ). Distinguishable from *longiseta* (and *deliensis* and allies) by the relative and actual greater width of the scutum—i.e., PW with a mean of 92 instead of 72 as in *longiseta*. A-P about 37, not 26 μ . The palpal claw is 2-pronged as in *T. longiseta*; it is trifurcate in *T. deliensis*. (See fig. 43, p. 60)

Description of Larva.—**Body:** About 446×280 μ in moderately engorged holotype; very large in fully engorged individuals (1120×800 μ). Eyes 2+2, on ocular plate, distinct, subovate, but posterior eye usually slightly longer and narrower than anterior. **Gnathosome:** Chelicers each with a small subapical tooth or notch but lacking a more proximal denticle. Palpal formula N/N/BNN. Galeal seta B (sparsely). Palpal claw apparently bifurcate. **Scutum:** Subrectangular; somewhat less than twice as broad as long; anterior margin very shallowly biconcave; lateral margins somewhat concave; posterior margin slightly sinuous (reflecting the SBs). Sensillary bases inserted at level slightly anterior to PLs. Sensillae nude except for subapical short branches; about 65-70 μ long. AL setae with short barbs; somewhat longer than scutum (ASB+PSB=SD, Scutal Depth). PL setae about twice length of AL, or even longer; similar in structure. **Body Setae:** About 26-28 dorsal setae arranged 2. 6(8). 6. 6... the rest irregular; anteriormost about 85-92 μ long; with many short inconspicuous barbs. True ventral setae about 50 μ , subpectinate, about 14 VS, plus 6-10 caudal setae (CS) ca. 70 μ . Sensory setae as in *T. baluensis* n. sp. and in "akamushi group".

STANDARD MEASUREMENTS IN MICRONS, *T. pipellae* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$	
Holotype ...	...	78	91	33	40	14	37	59	85	123	87	$\frac{91}{78}$ =1.16	$\frac{91}{54}$ =1.7	$\frac{91}{40}$ =2.3	$\frac{91}{37}$ =2.46
Paratypes (19) Mean		80	93	32	39	15	38	61	89	125	91	1.15	1.7	2.38	2.44
Range (+ or -) ...		3	3	2	2	2	3	5	8	7	0.05	0.05	0.07	0.05	

Type Material.—Holotype (B9013-1) and 21 paratypes ex *Prionodon linsang gracilis* Horsfield, a civet (Viverridae), Mt. Kinabalu, Tenompok, elev. 4,500 ft., 17. vii. 1951 (R. Traub and J. R. Audy). Sixteen other paratypes as follows: ex *Callosciurus notatus*, *ibid*, 18. vii; 6 ex *Helictis everetti*, a ferret-badger, *ibid*, 8, vii; 1 ex *Rattus alticola*, *ibid*, 16. vii; 4 ex *Rattus mulleri*, Jesselton, 8. vii. 1951 (D. H. Johnson).

and Phang Ang-Wah). (A number of topotypes were collected in 1952. A single specimen (C.O.R.U. 17014), not included in the type series, came from *Echinosorex gymnurus*, moon-rat (Erinaceidae), Tinjar, Sarawak, 15. v. 1950 (Tom Harrison and Ben Ensoll). Paratypes distributed as for *T. flagellifera* n. sp.

Remarks.—*T. (L.) pipellae* is also near *T. (L.) fulleri* Ewing, 1945 in general configuration and in the subpectinate character of the typical ventral seta and regarding the long dorsal setae with appressed or short barbs (fig. 42, *T. fulleri*). In *T. fulleri*, however, the scutum (fig. 43) is very definitely biconvex caudally, and the sensillary bases are in a line with PL bases; while the PLs are only about twice the scutal depth or less. The caudal or postanal ventral setae (fig. 44) are more pectinate than in the new species.

The name *pipellae*, suggesting the letters PL, is a mnemonic for this species with remarkably long posterolateral setae.

Trombicula (Leptotrombidium) pilalta n. sp. (figs. 54-61, pp. 64, 65).

Diagnosis of Larva.—A species characterized by the following: a broad but relatively shallow scutum (PW over 92, SD=55-55 μ); posterior margin of scutum arcuate; sensillae with proximal half nude, distal half frayed; posterolateral setae (PLs) fairly long (77 μ); AM seta very long (over 80 μ); with about 42 dorsal setae with anterior rows arranged 2-10-10; palpal claw bifurcate. Close to *T. (L.) pipellae* n. sp., *T. (L.) akamushi* (Brumpt, 1910) and *T. (L.) longiseta* Womersley, 1952, but separable as shown in following table (measurements are means, expressed in microns):

Character							<i>pilalta</i>	<i>pipellae</i>	<i>akamushi</i>	<i>longiseta</i>
AM	...	...	...	...	...	...	87	89	58	57
PL	...	...	...	...	...	...	77	126	60	109
Palpal Claw, prongs	...	...	...	...	...	...	2	2	3	2
PW	...	...	...	...	...	...	95	93	78	73
Ratio: PW/SD	...	...	...	...	...	...	1.9	1.7	1.9	1.7
Ratio: PW/Coxa-II	...	...	...	...	...	...	1.37	1.15	1.45	—
Posterior Margin of Scutum...	...	...	...	...	...	...	Arcuate	Slightly sinuate	Slightly arcuate	Sinuate
No. of Dorsal Setae	...	...	...	...	...	...	38-42	28	32-40	28
Typical Rows of Dorsal Setae	...	...	...	...	...	...	2.10.10	2.8.6	2.10.8	2.8.8.6

Description of Larva.—**Body:** About 490 $\times$ 305 μ in fairly engorged holotype. Eyes 2+2 on ocular plate. **Gnathosome:** Chelicers rather strongly curved with a minute subapical denticle or incision on mesal margin, somewhat proximal to usual lateral notch near apex. Palpal formula N/N/BNN. Palpal claw 2 pronged. Galeal seta B. **Scutum:** Subrectangular, almost twice as broad as long, anterior margin slightly sinuate; lateral margins shallowly concave, almost straight; posterior margin arcuate or rounded in the main, but flattened near insertion of PLs. Scutal setae with many even, fairly short barbs. PLs about 1½ times scutal depth; AM about 1½ times. Sensillae about 98 μ long, proximally nude, frayed or delicately branched beyond midpoint. Sensillary bases at about level of PLs. **Body Setae:** About 38/42 (usually over 40) dorsal setae arranged 2. 10. 10. 10. (8)... the rest irregular, with thin rather short barbs. True ventrals ca. 45 μ subpectinate, 20 in number, plus 10-12 caudal setae, postanal, 60 μ , resembling DS. **Legs:** Sensory setae as in *T. (L.) baluensis* n. sp. and “*akamushi* group”.

STANDARD MEASUREMENTS IN MICRONS, *T. pilalta* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype	85	97	38	36	15	33	52	84	74	64	$\frac{97}{71}$ =1.37	$\frac{97}{51}$ =1.9	$\frac{97}{36}$ =2.7	$\frac{97}{33}$ =2.9
Paratypes (20) Mean	84	97	39	38	15	33	54	87	76	65	1.35	1.8	2.53	2.9
Range (+ or -) ...	5	5	2	3	1	2	4	6	4	5	0.06	0.1	0.18	0.05

Type Material.—Holotype and 19 paratypes ex *Rattus rattus baluensis*, Mt. Kinabalu, Kamboranganh, elev. 7800 ft., 6. v. 1952 (J. R. Audy). Ten other paratypes as follows: 9 *Tupaia montana* tree shrew, and 1 ex *Dendrogale*, a tree shrew, *ibid*, but 26. vii. 1951. (R. Traub). Holotype (U.S.N.M. 2016) deposited in U.S. National Museum, paratypes distributed as for *T. flagellifera* n. sp.

STUD. INST. MED. RES.

Trombicula (Leptotrombidium) tarsala n. sp. (figs. 62-69, pp. 66, 67).

Diagnosis of Larva.—Near *T. deliensis* but separated at once by the enlarged striate tarsala (spur) on Leg I, being about as long as the tarsus is broad at this point, instead of scarcely half so. The tarsala II correspondingly enlarged, and in about the same proportion to breadth of tarsus.

Description of Larva.—*Body*: About $351 \times 245\mu$ in fairly engorged holotype. Eyes $2+2$ on ocular plate, the anterior eye slightly the larger. *Gnathosome*: Chelicers each with a tricuspid cap. Palpal formula N/N/BNN. Palpal claw perhaps 3-pronged, but not determinable in specimens extant. Galeal seta B. Scutum almost two-thirds long as broad; posterior margin somewhat convex, evenly so; anterior margin essentially slightly concave but medially minutely sinuate; lateral margins sloping gently mesad towards AL with short "shoulders" at insertion of PLs. AM slightly longer than PLs which in turn are half-again as long as ALs; the scutal bristles barbed, the barbs rather appressed in AM and PL. Sensillae nude for basal two-thirds, then lightly branched. Bases of sensillae inserted slightly anterior to level of PLs. *Body Setae*: Dorsal setae about 26 in number arranged 2. 6. 6. 4. 4. 2: similar to PLs. True ventral setae $26-30\mu$ plumose, numbering 14-16, plus about 6 caudal setae, ca. $40-52\mu$ resembling DS but at times more plumose. *Legs*: Sensory setae as in *T. baluensis* but with tarsala of Leg I relatively very large, submarginal, slightly curved, about subequal to breadth of tarsus at level of base of tarsala; tarsala of Leg II as in I but more median.

STANDARD MEASUREMENTS IN MICRONS, *T. tarsala* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype ...	...	59	70	28	28	11	26	42	68	66	70/59 =1.22	70/39 =1.8	70/28 =2.5	70/26 =2.7
Paratype ...	...	59	66	26	28	12	27	45	69	63	70/58 =1.20	70/40 =1.75	70/28 =2.5	70/27 =2.5

Type Material.—Holotype (C.O.R.U. 21314) ex *Rattus mülleri*, Forest Reserve, mile 5 Stapok Road, Kuching, Sarawak, 30. viii. 1952; and one Paratype (No. 21288), same host species and locality, 31. viii. 52 (Tom Harrison).

Trombicula (Leptotrombidium) micula n. sp. (figs. 87-94, pp. 72, 73).

Diagnosis of Larva.—Close to *T. deliensis* but with a scutum which is actually smaller and proportionately less deep (PW with a mean of 63 microns, $SD=31$), the ratio $PW/SD=2$, not 1.7-1.8, and $PW/A-P$ is 3.1, not 2.2-5; SB nevertheless similar in both species ($28-30\mu$); posterior margin of scutum rather evenly convex, instead of being slightly convex or quite straight and immediately behind PLs; sensillae bases inserted at the level of PLs or slightly behind, not somewhat anterior to PLs.

Description of Larva.—*Body*: About $201 \times 137\mu$ in partially engorged holotype. Eyes $2+2$ on ocular plate; posterior eye somewhat the smaller. *Gnathosome*: Chelicers each with the usual subapical notch. Palpal formula N/N/B(b)NN but dorsal tibial seta only slightly frayed, not truly barbed. Palpal claw 3-pronged, Galeal seta B. *Scutum*: About twice as broad as long; subrectangular but for rather arcuate posterior margin, anterior and lateral margins fairly straight except for typical bulge at level of insertion of ALs or PLs. PL slightly longer than AM which is somewhat longer than ALs: these setae with short cilia or barbs, but longest on AL. Sensillae with proximal half nude; apical half lightly branched. *Body Setae*: About 28 dorsal setae usually arranged 2. 8. 6. (7). 6. 4. 2.; similar to PLs. True ventral setae ca. 21μ , sparsely plumed, numbering about 16, plus 6-8 cadual setae, postanal, 26μ , resembling DS. *Legs*: sensory setae as in *baluensis* n. sp. and others of "akamushi group".

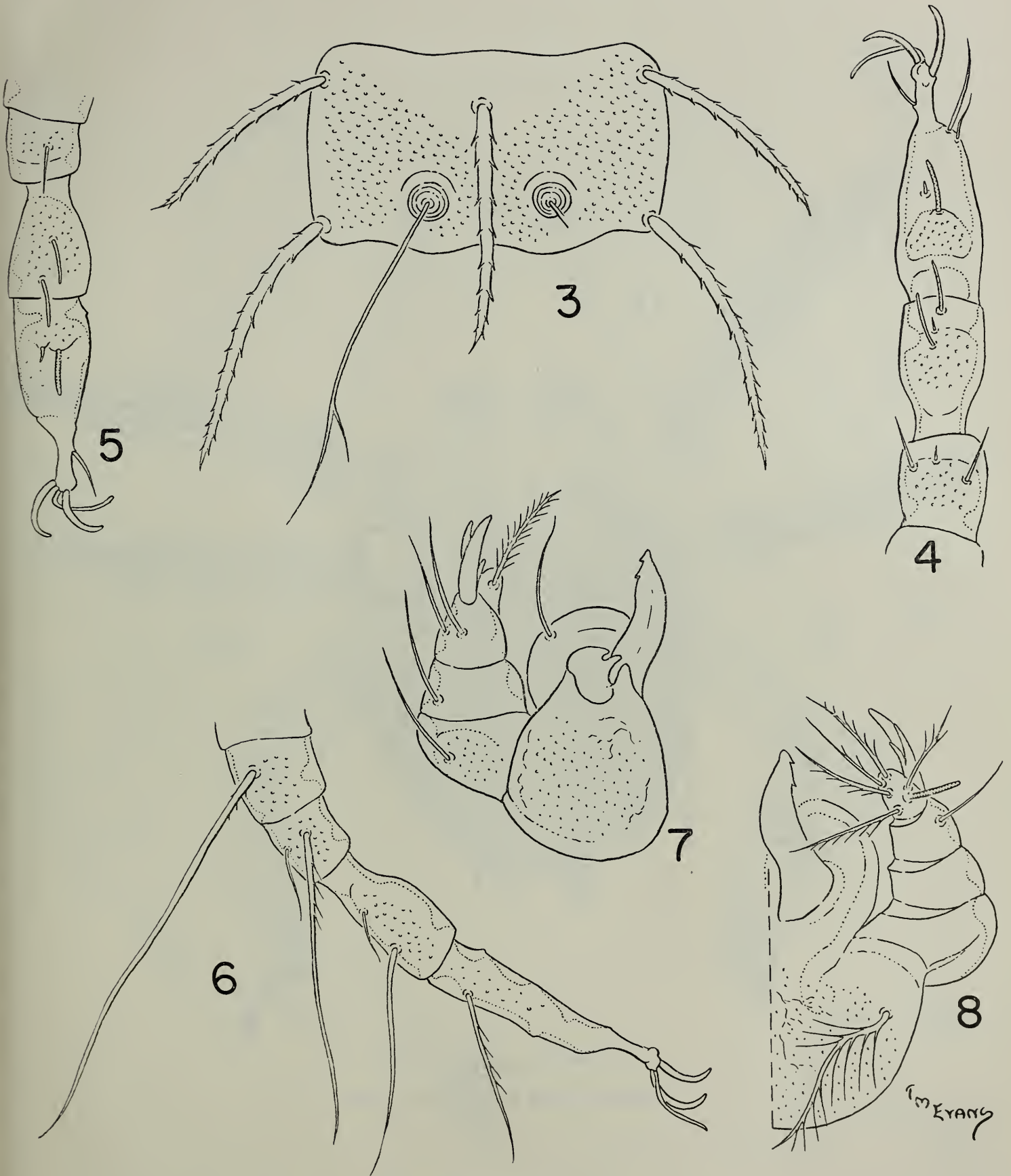
STANDARD MEASUREMENTS IN MICRONS, *T. micula* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Holotype ...	...	58	62	30	20	11	20	27	35	40	62/50 =1.24	62/31 =2.0	62/20 =3.1	62/20 =3.1
Paratypes (8) Mean		56	62	29	19	12	20	28	35	42	1.27	2.0	3.1	3.1
Range ...	...	3	4	1	2	1	2	2	3	4	0.05	0.06	0.09	0.02

Type Material: Holotype and 7 paratypes ex *Nannosciurus melanotis*, a pigmy squirrel, Sarawak, Kuching, Stapok Forest Reserve, xi. 1951. (Tom Harrison). Two paratypes ex *Callososciurus notatus*, *ibid.* Holotype (U.S.N.M. 2017) in U.S. National Museum. Paratypes in that institution and in collections of Colonial Office Medical Research Unit and of R. Traub.



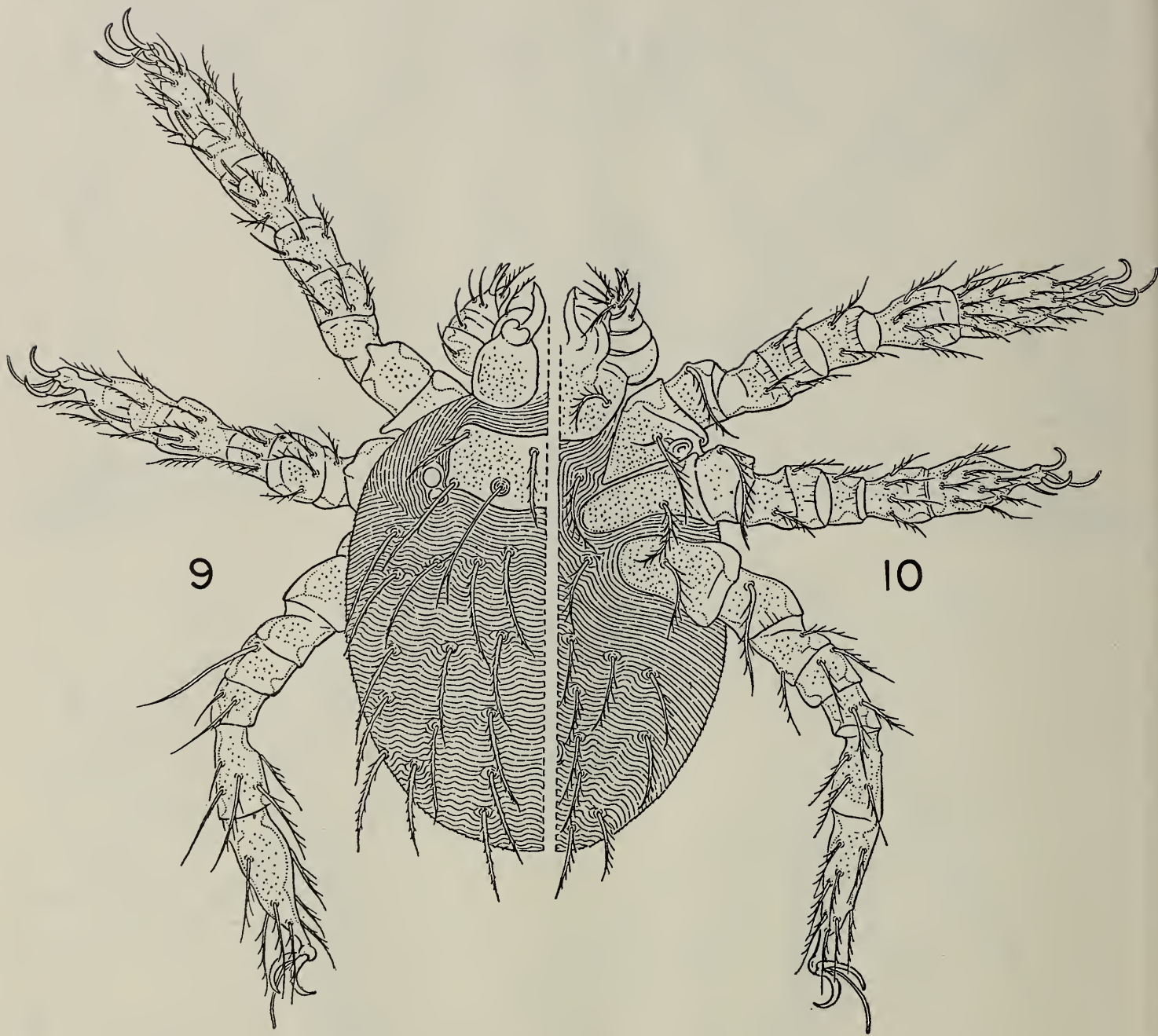
Trombicula flagellifera n. sp.
Dorsum (1) and Venter (2) of Larva



Trombicula flagellifera n. sp.

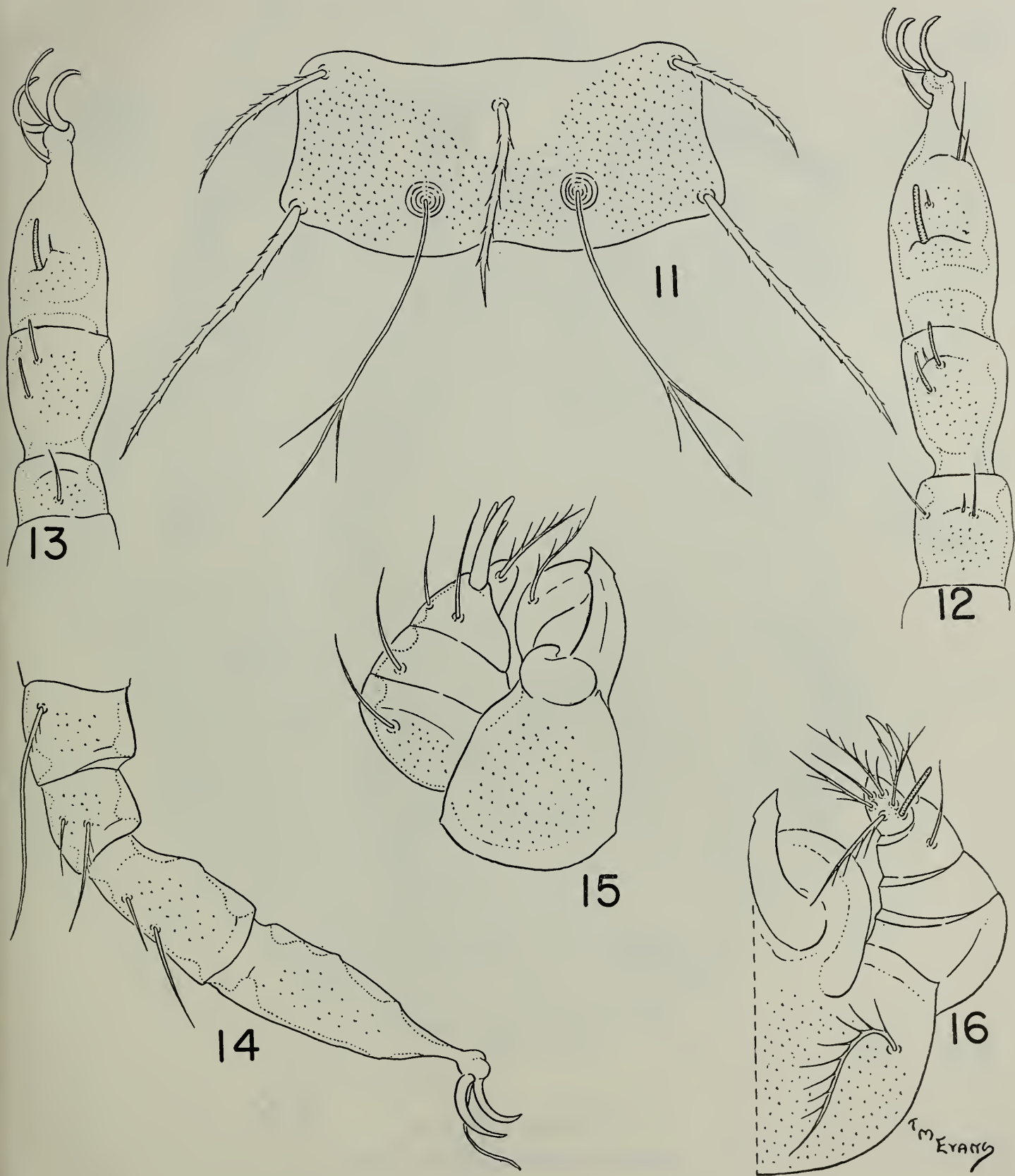
Scutum 3
Legs I, II, III 4, 5, 6

Mouthparts, Dorsal 7
Ventral 8



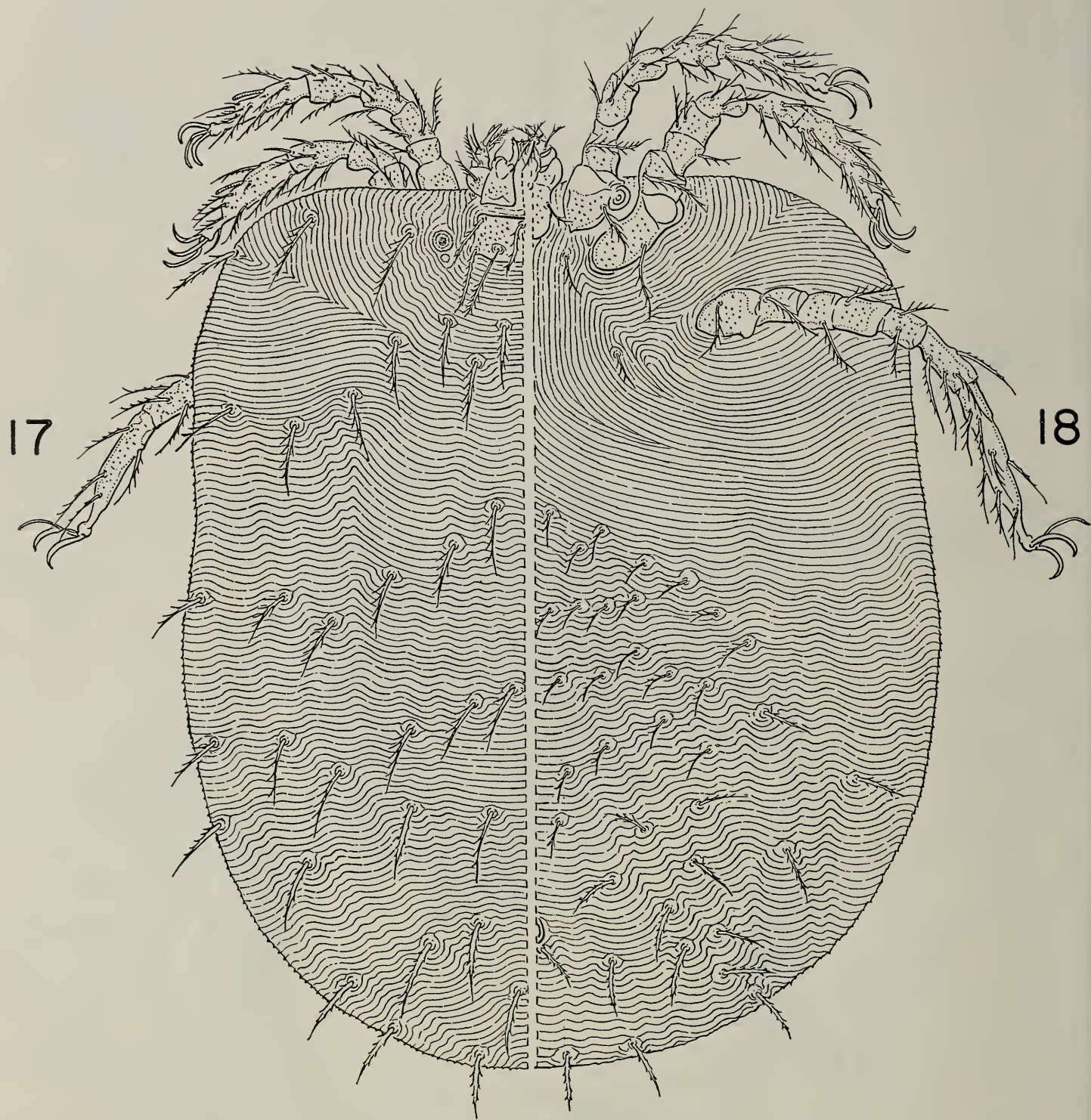
Trombicula tuhana n. sp.

Dorsum (9) and Venter (10) of Larva



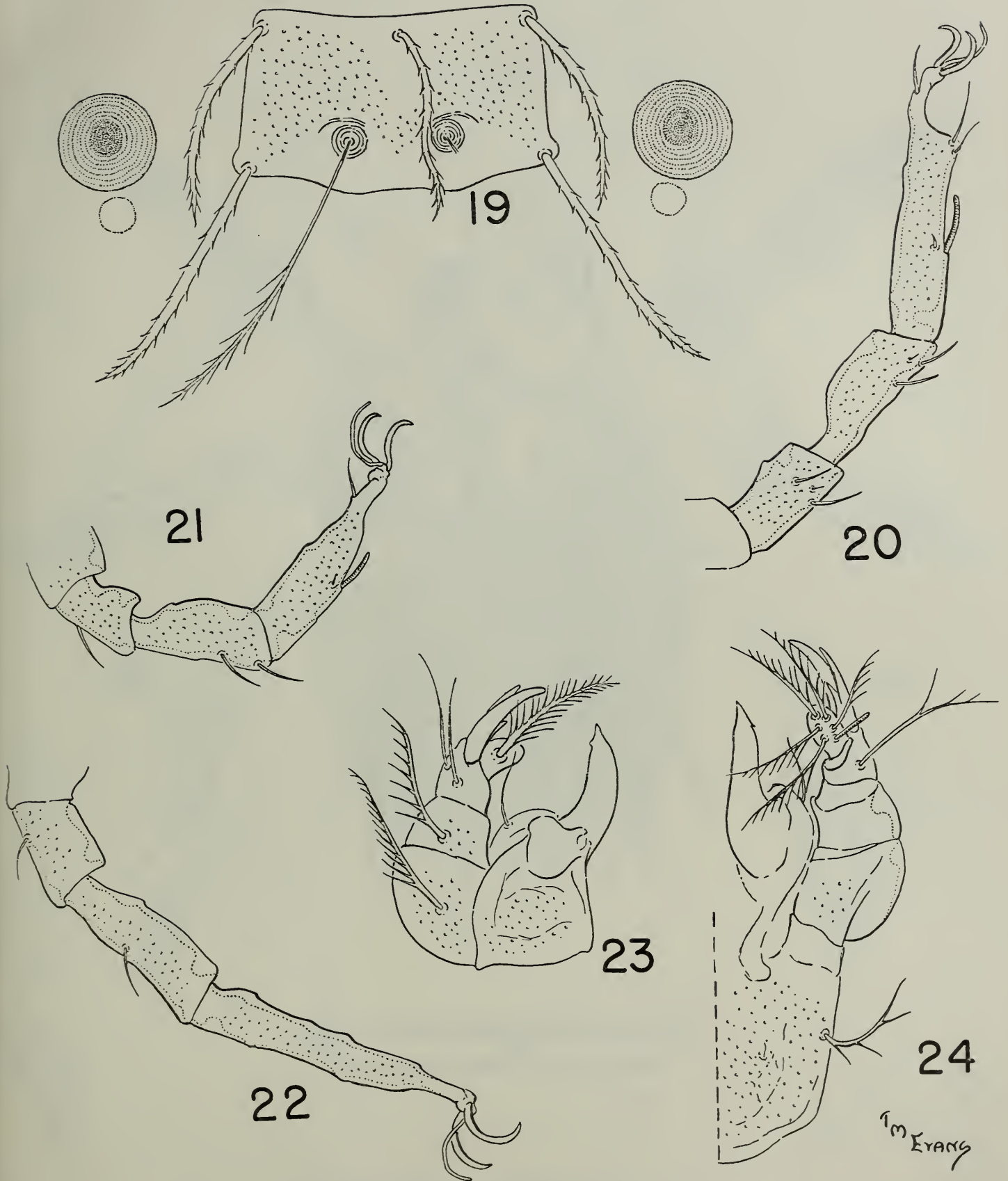
Trombicula tuhana n. sp.

Scutum	11	Mouthparts, Dorsal	15
Legs I, II, III	12, 13, 14	Ventral	16



Trombicula vorca n. sp.

Dorsum (17) and Venter (18) of Larva



Trombicula vorca n. sp.

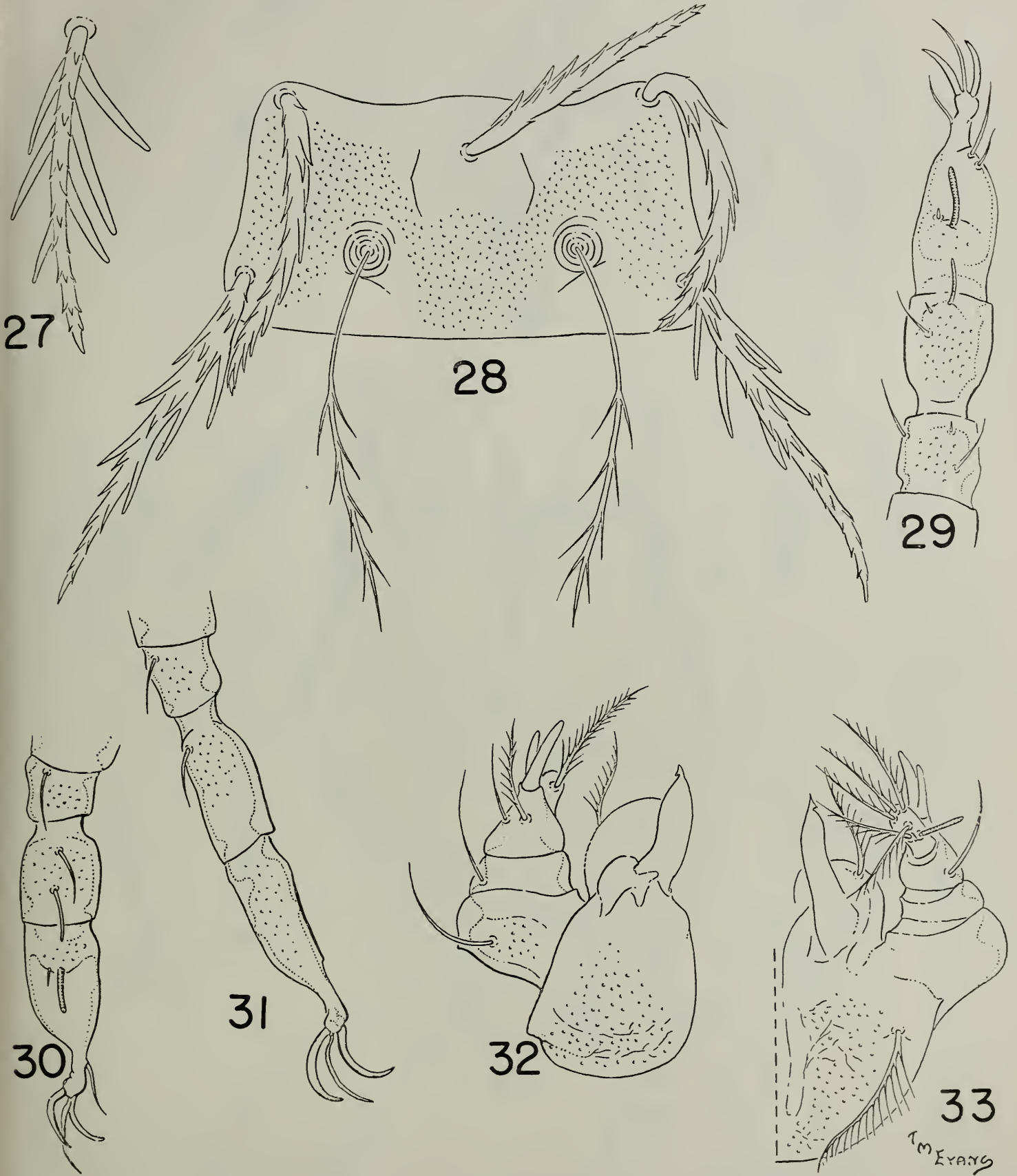
Scutum 19
Legs I, II, III 20, 21, 22

Mouthparts, Dorsal 23
Ventral 24



Trombicula (Leptotrombidium) baluensis n. sp.

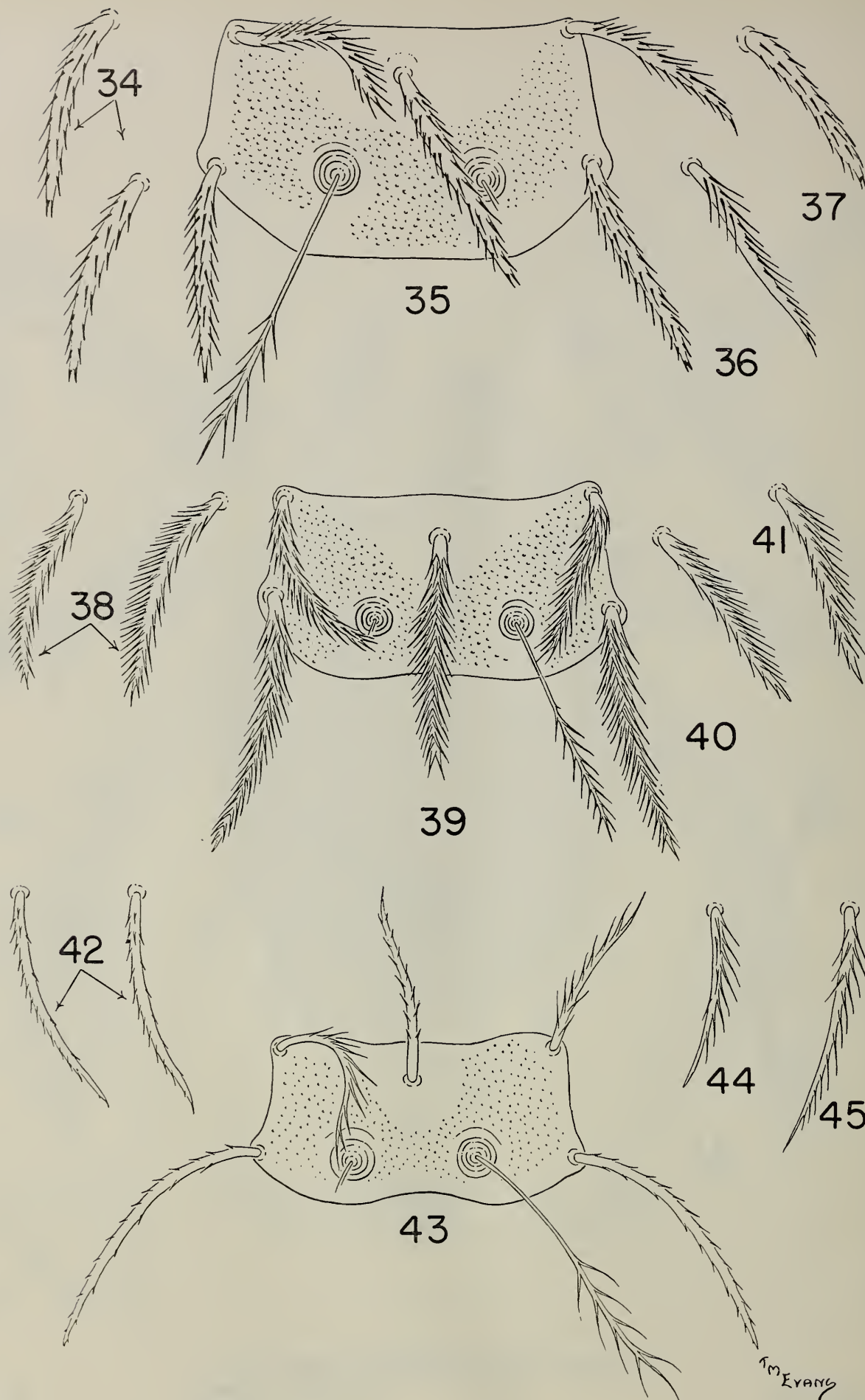
Dorsum (25) and Venter (26) of Larva



Trombicula (Leptotrombidium) baluensis n. sp.

Dorsal Seta	.	.	.	.	27
Scutum	.	.	.	.	28
Legs I, II, III	.	.	.	.	29, 30, 31

Mouthparts, Dorsal	.	.	.	.	32
Ventral	.	.	.	.	33



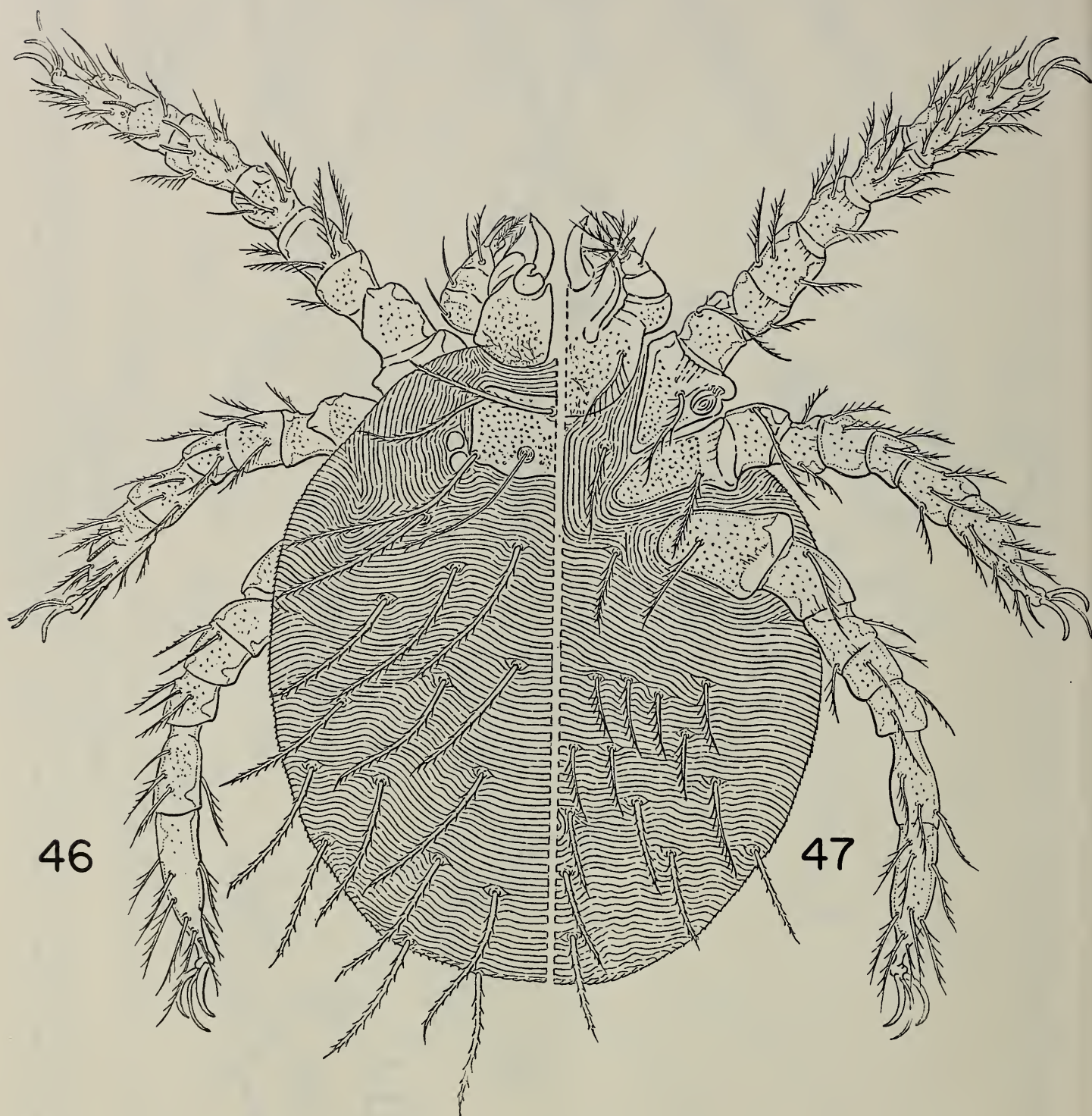
- 34-37 *Trombicula (Leptotrombidium) scutellaris* Nagayo et al., 1920
 38-41 *Trombicula (Leptotrombidium) intermedia* Nagayo et al., 1920
 42-45 *Trombicula (Leptotrombidium) fulleri* Ewing, 1945

Showing, in order, Dorsal Setae, Scutum, Ventral Seta, and Caudal (Post-anal) Seta



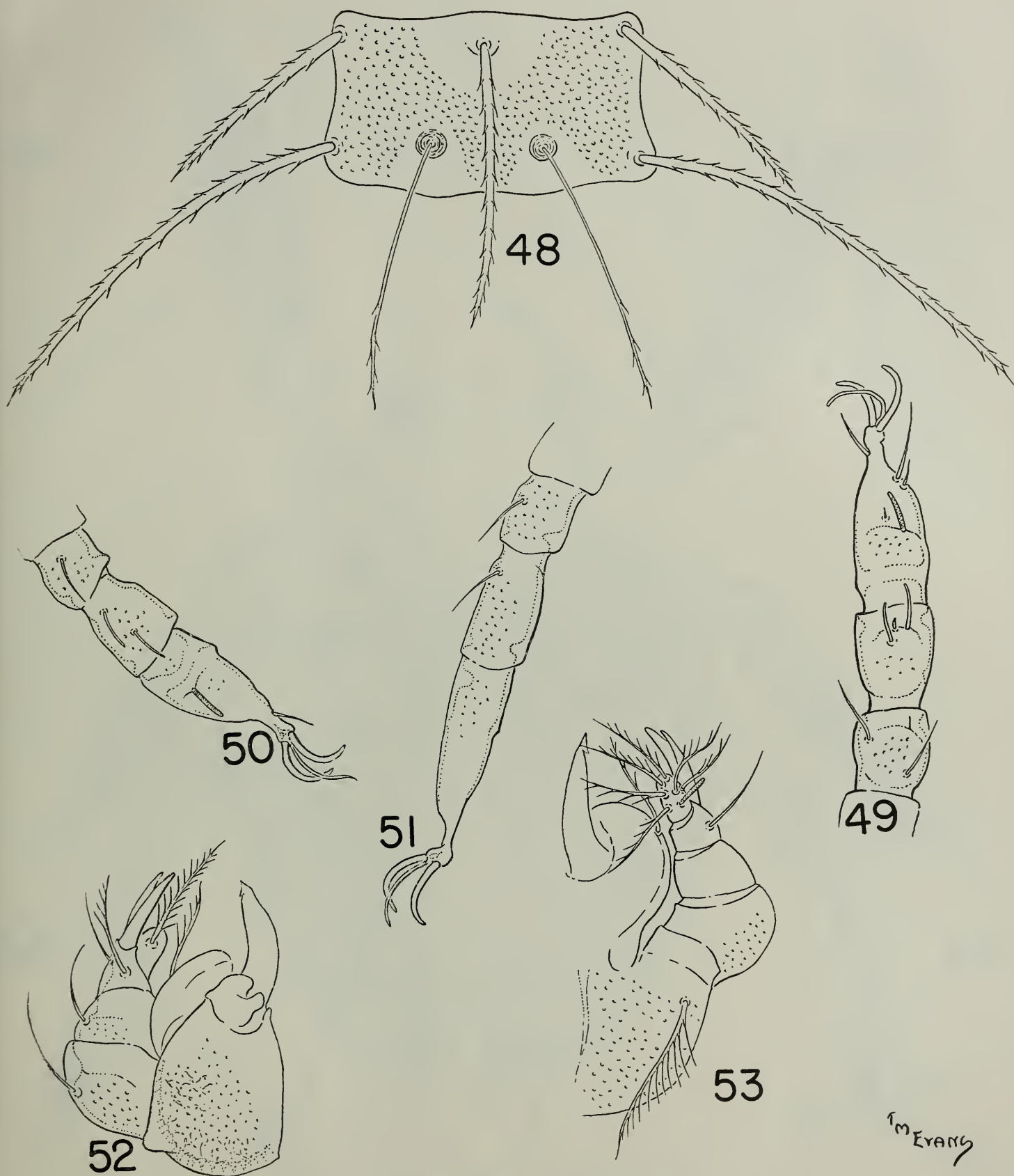
Collecting Areas in North Borneo.

The smoothed-out contours are at 1,000m. and 2,000m. There is no continuous road from Jesselton to Beaufort, but there is a railway line going through Beaufort to Melalap near Keningau. Internal air services now connect Jesselton, Keningau, Ranau, Kudat and Sandakan.



Trombicula (Leptotrombidium) pipellae n. sp.

Dorsum (46) and Venter (47) of Larva



Trombicula (Leptotrombidium) pipellae n. sp.

Scutum 48
 Legs I, II, III 49, 50, 51

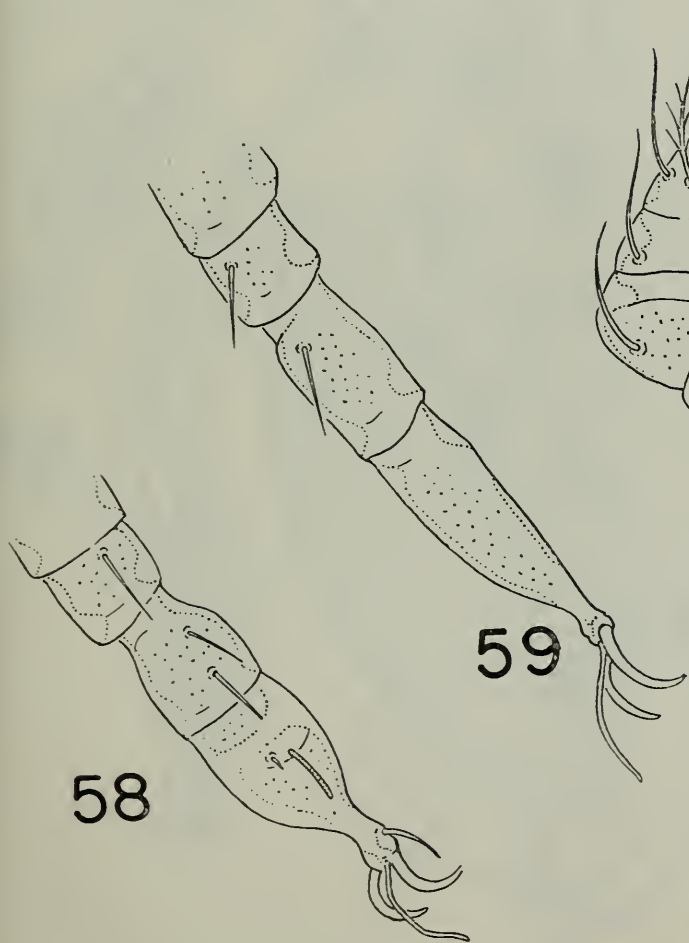
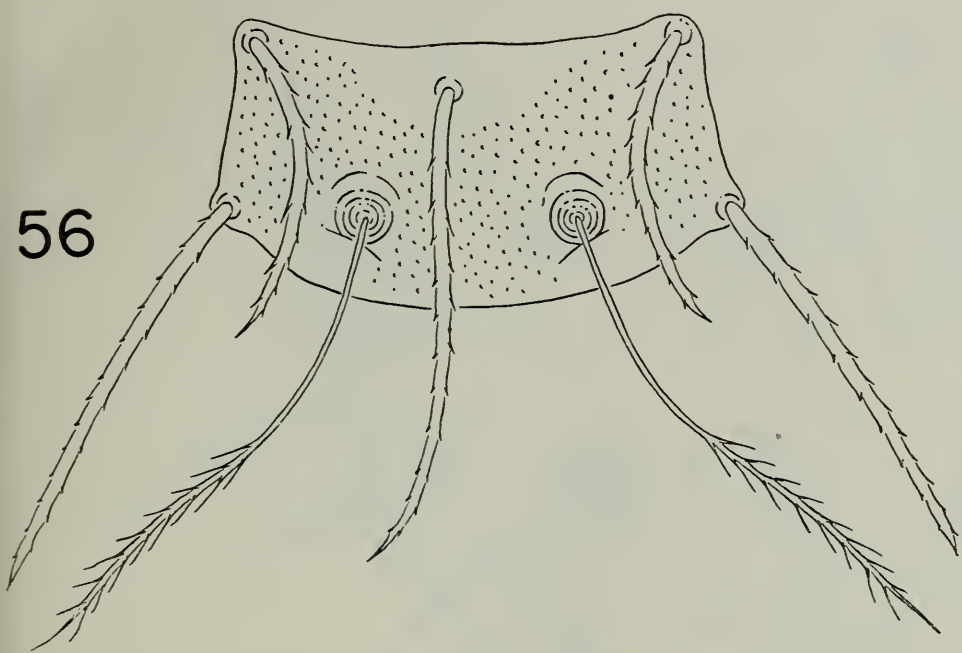
Mouthparts, Dorsal 52
 Ventral 53

Im. Evans



Trombicula (Leptotrombidium) pilalta n. sp.

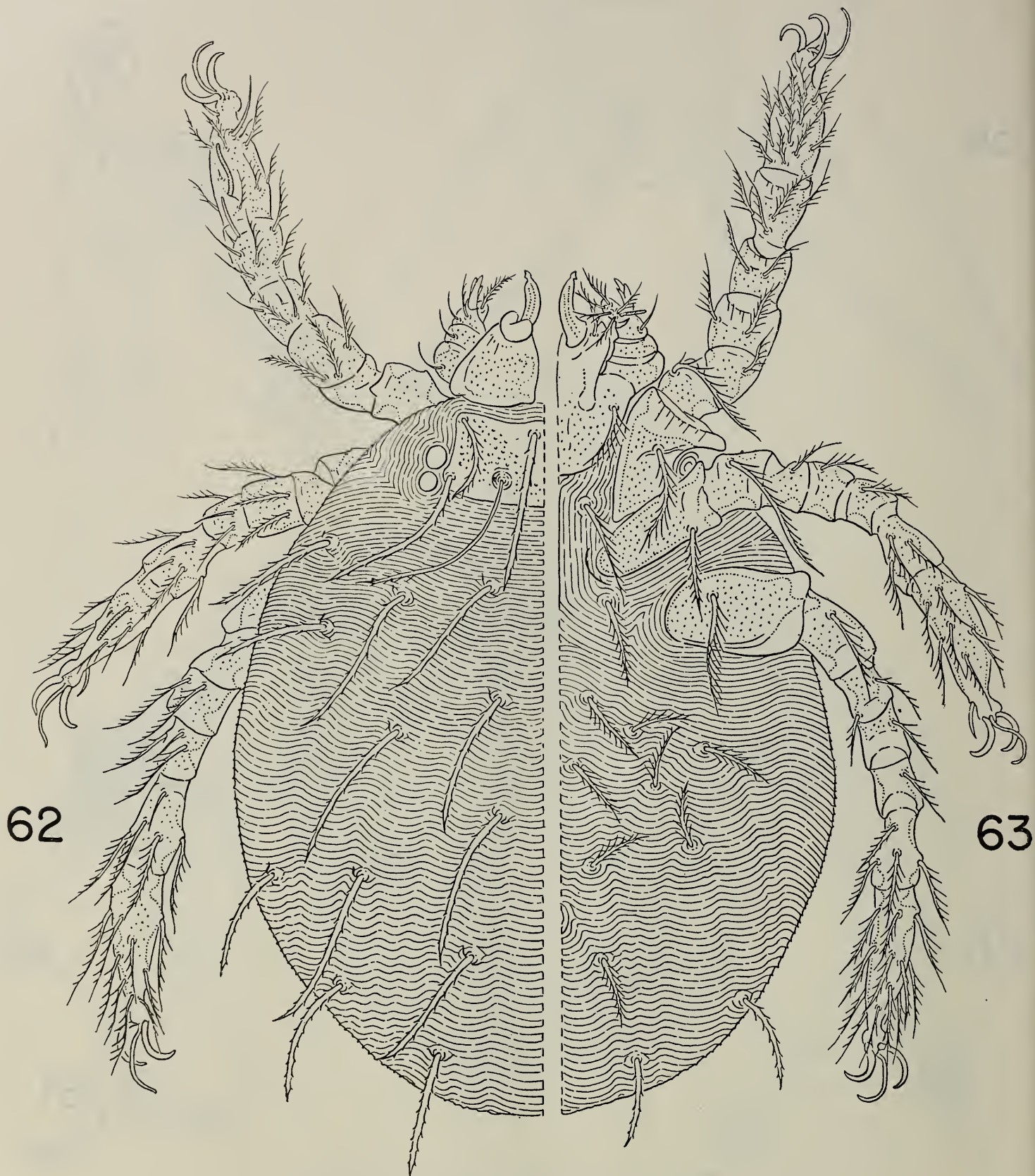
Dorsum (54) and Venter (55) of Larva



Trombicula (Leptotrombidium) pilalta n. sp.

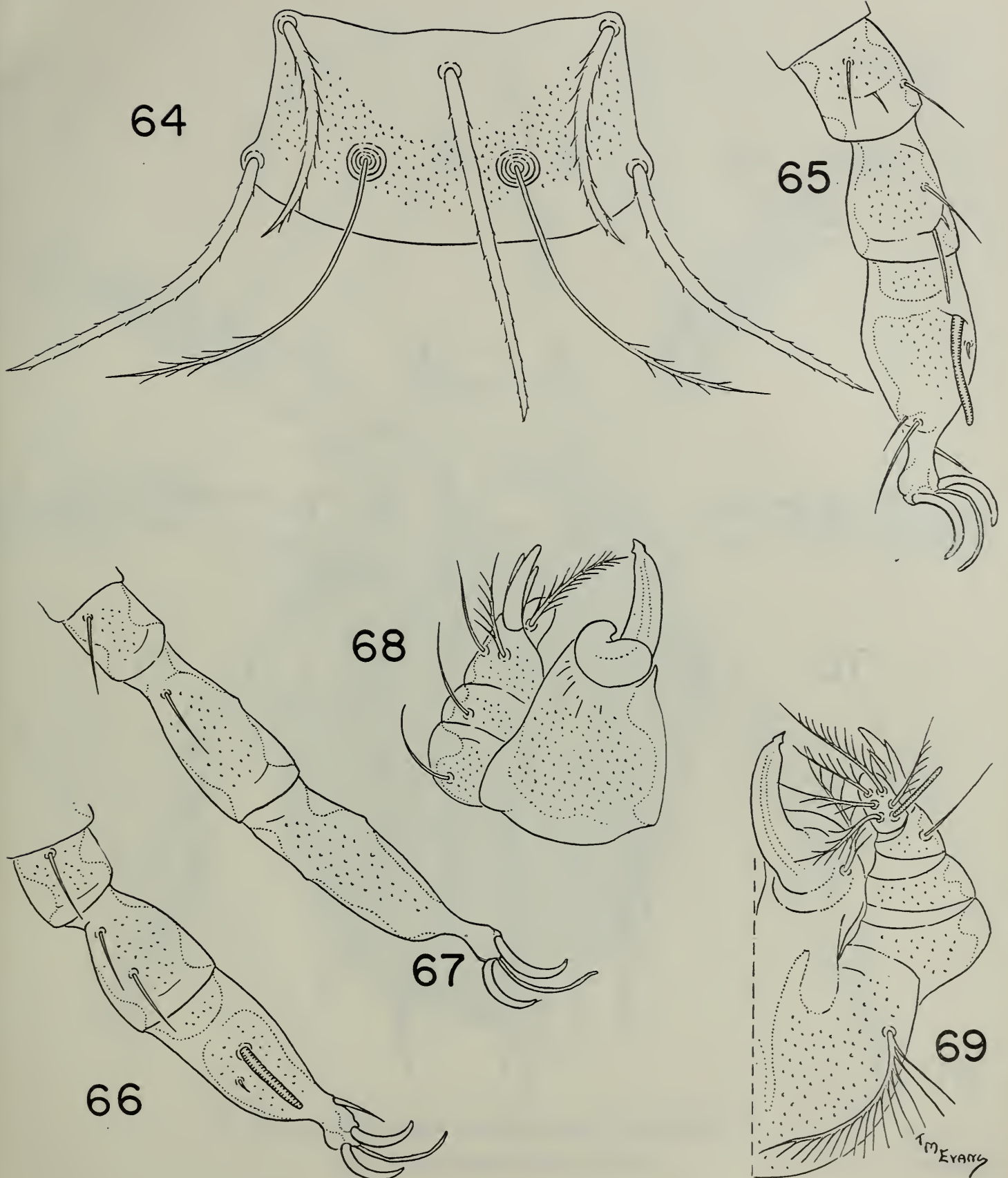
Scutum 56
Legs I, II, III 57, 58, 59

Mouthparts, Dorsal 60
 Ventral 61



Trombicula (Leptotrombidium) tarsala n. sp.

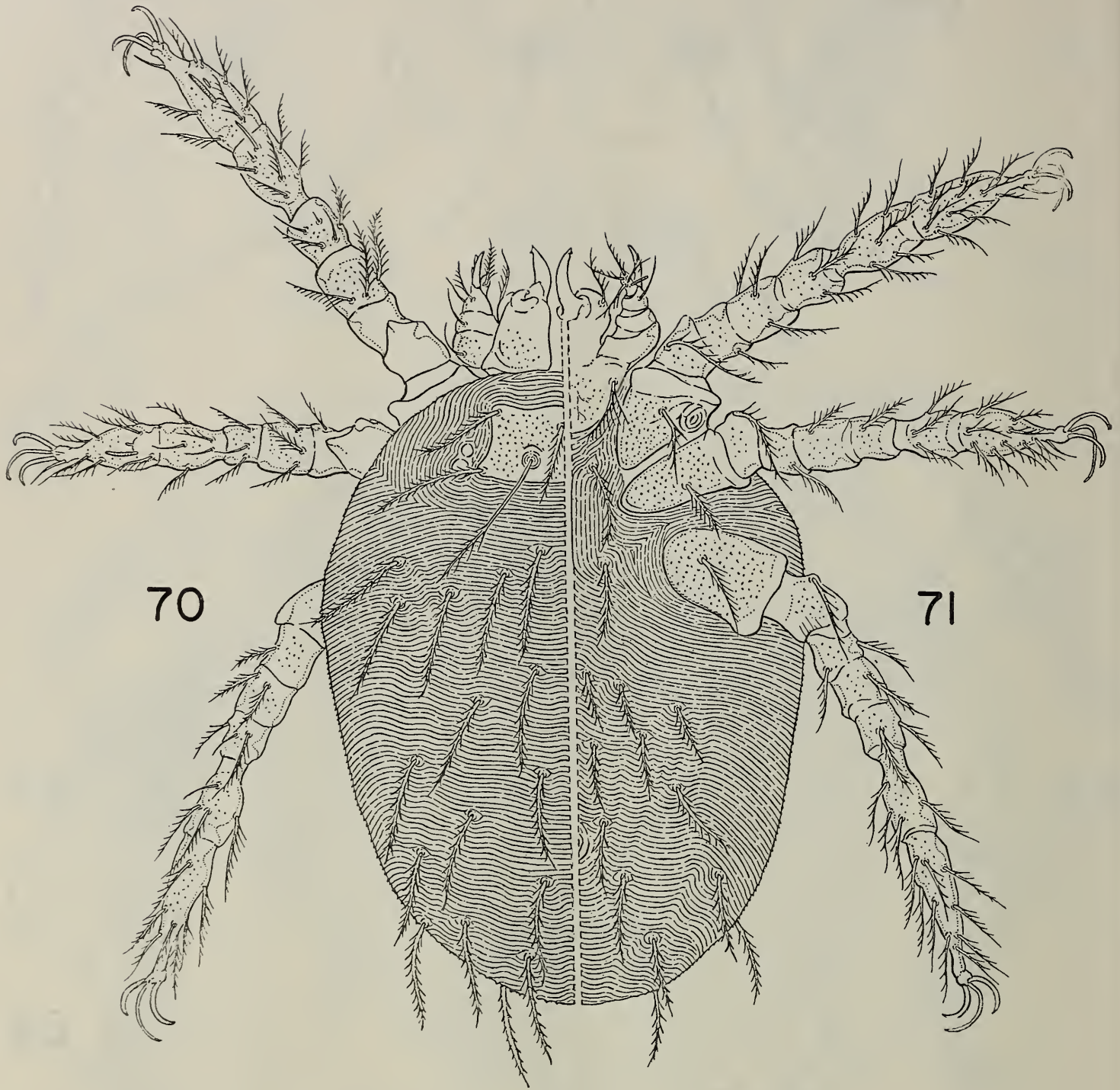
Dorsum (62) and Venter (63) of Larva



Trombicula (Leptotrombidium) tarsala n. sp.

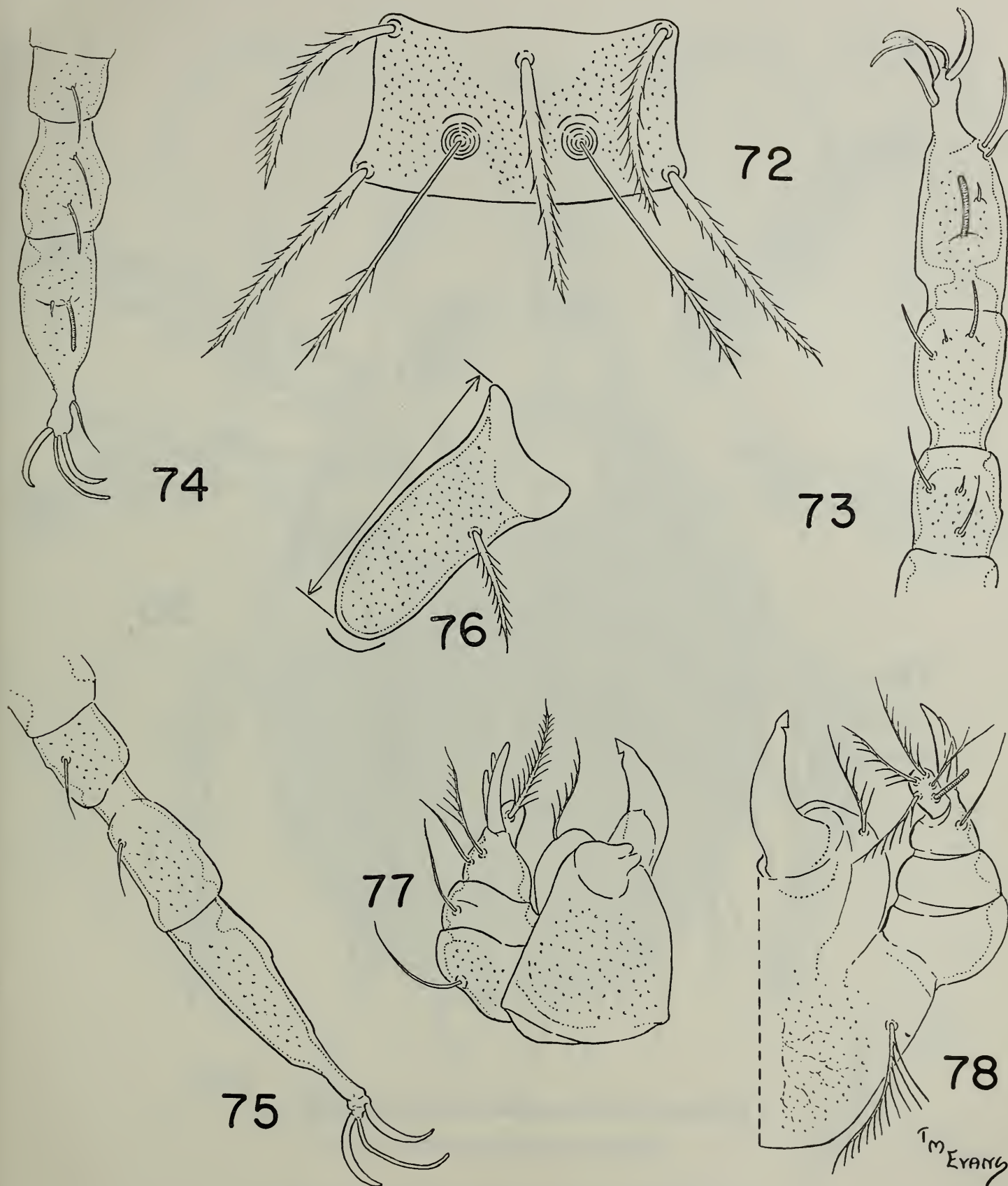
Scutum 64
 Legs I, II, III 65, 66, 67

Mouthparts, Dorsal 68
 Ventral 69



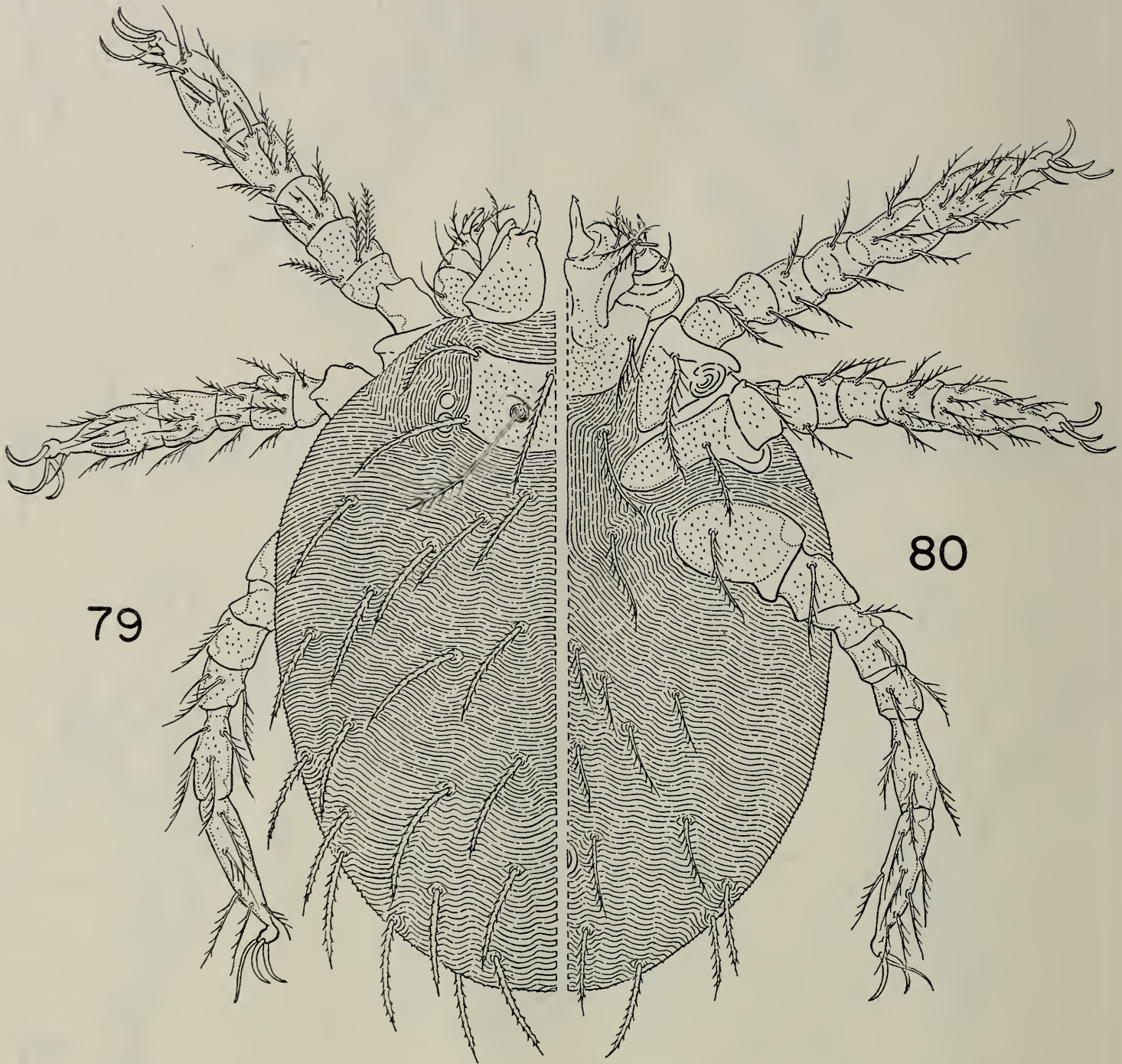
Trombicula (Leptotrombidium) deliensis Walch, 1922

Dorsum (70) and Venter (71) of Larva



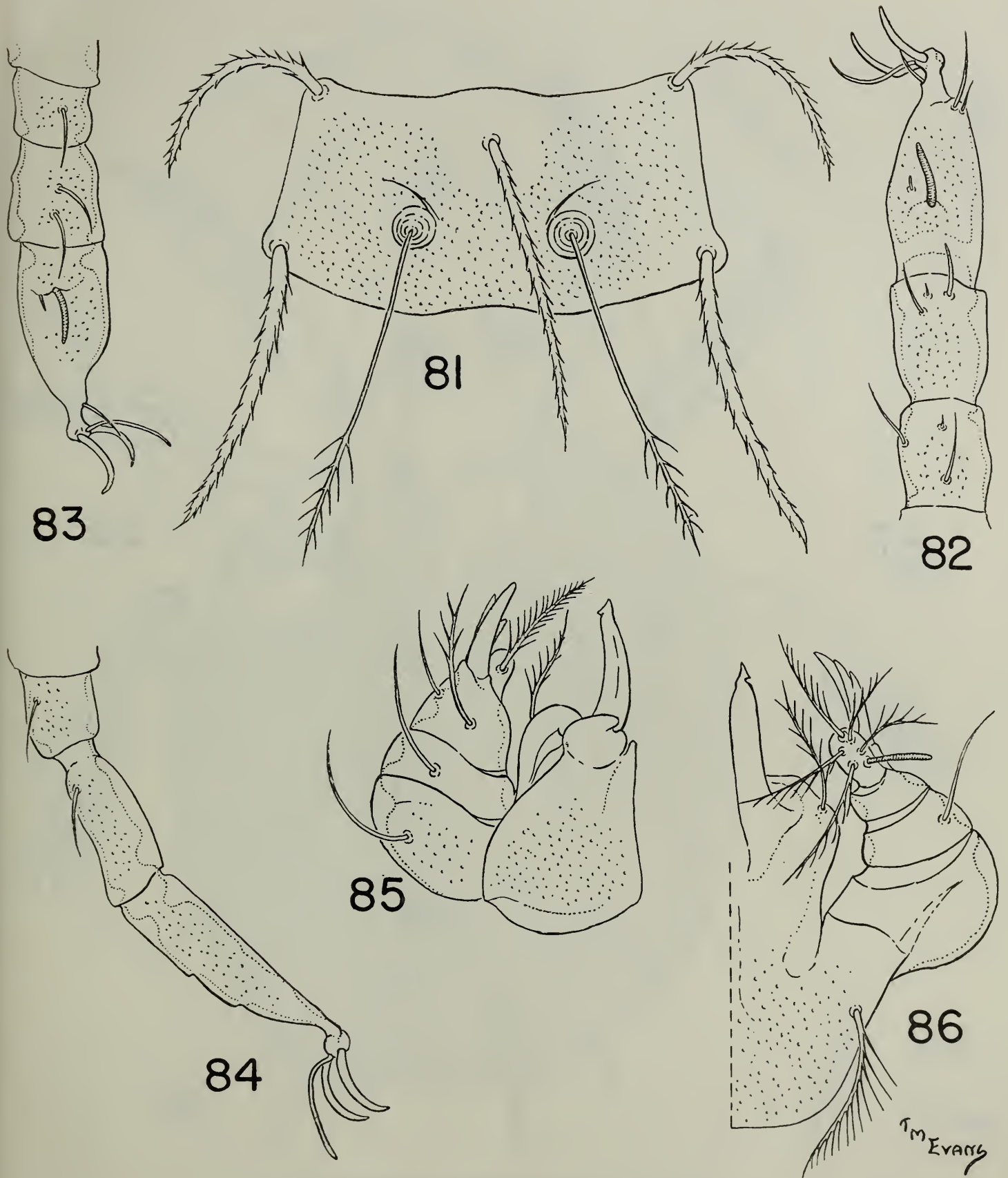
Trombicula (Leptotrombidium) deliensis Walch, 1922

Scutum	72	Mouthparts, Dorsal	77
Legs I, II, III	73, 74, 75	Ventral	78
Coxa II, showing measurement for the ratio PW/Coxa-II			76



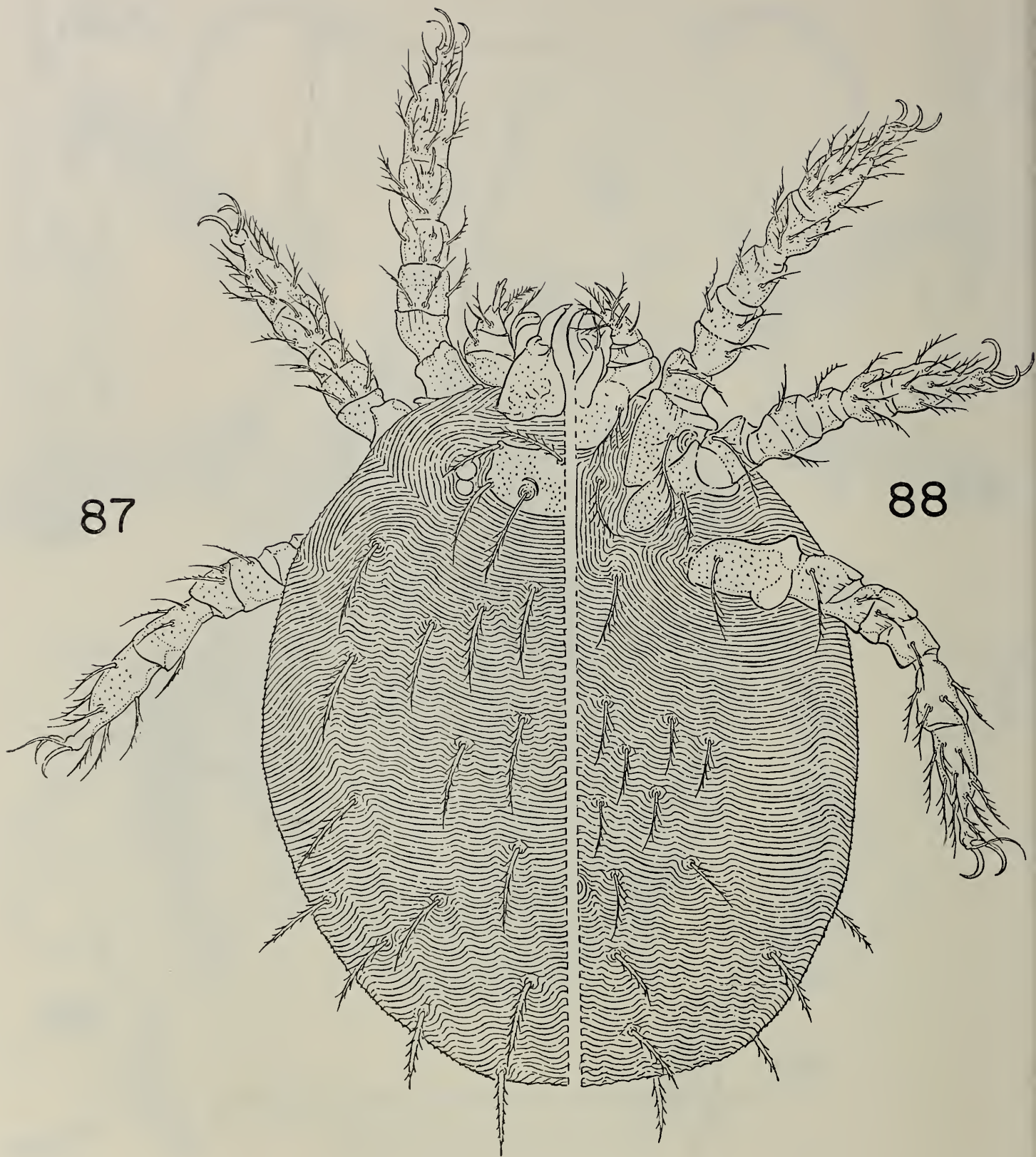
Trombicula (Leptotrombidium) akamushi Brumpt, 1910

Dorsum (79) and Venter (80) of Larva



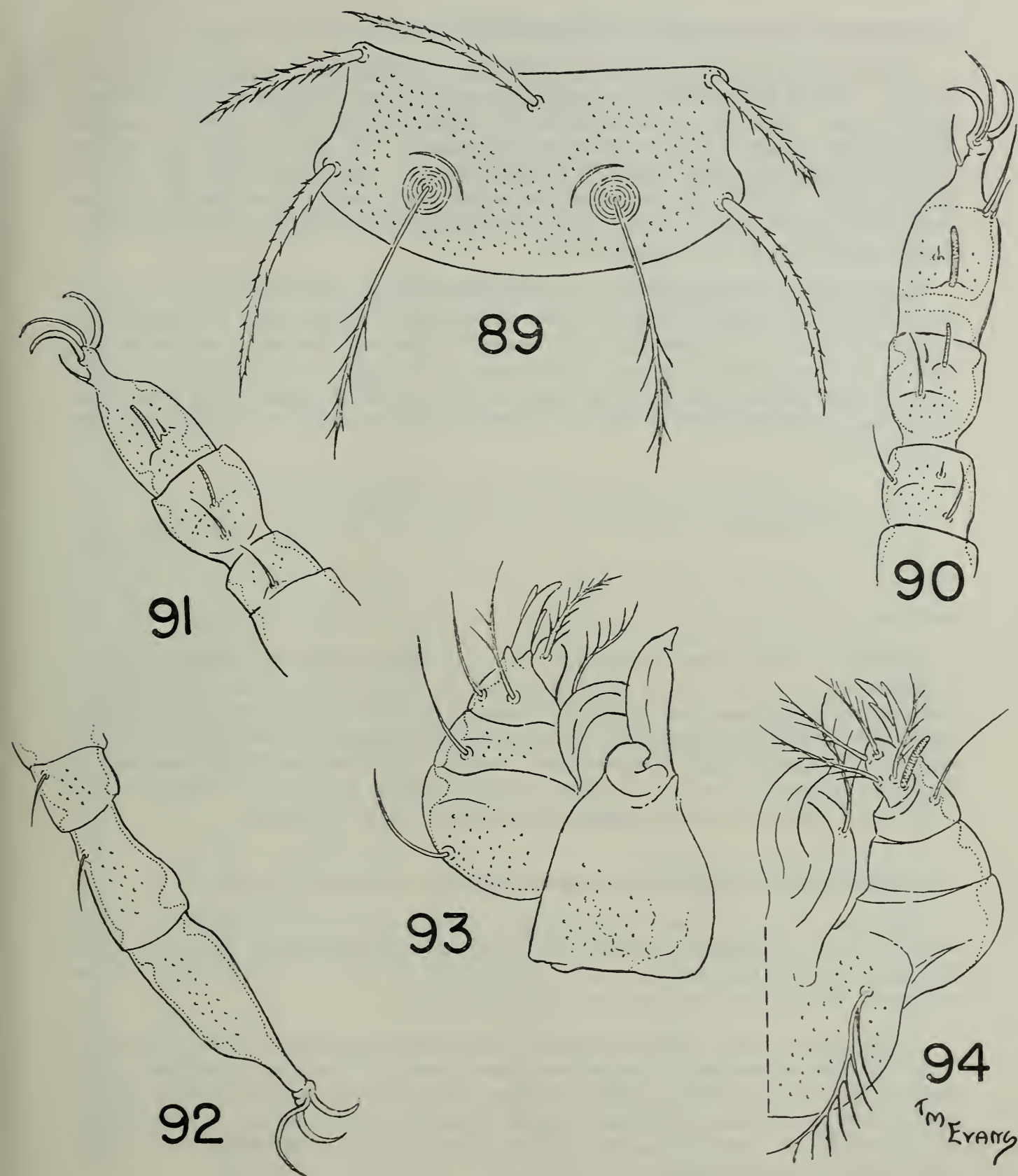
Trombicula (Leptotrombidium) akamushi Brumpt, 1910

Scutum	81	Mouthparts, Dorsal	85
Legs I, II, III	82, 83, 84	Ventral	86



Trombicula (Leptotrombidium) micula n. sp.

Dorsum (87) and Venter (88) of Larva



Trombicula (Leptotrombidium) micula n. sp.

Scutum 89
 Legs I, II, III 90, 91, 92

Mouthparts, Dorsal 93
 Ventral 94

Trombicula (Leptotrombidium) deliensis Walch, 1922 (fig. 70-78, pp. 68, 69).

Diagnosis of Larva.—Palpal formula N/N/BNN. Palpal claw 3-pronged. Galeal seta plumose. Scutum rather rectangular, but lateral margins somewhat concave, posterior margin slightly convex. Bases of sensillae inserted only slightly anterior to level of PLs. Sensillae with proximal portion nude; apical third sparsely plumed. PL seta less than half again as long as SD; not much longer than AL, subequal to AM. Scutal setae fairly well plumed, the barbs short. Dorsal setae resembling those of scutum; about 28-32 in number, the rows nearly always commencing 2.8.6.6. With 12-14 ventral setae plus 6-8 caudals (postanals). Sensory setae of legs as in *T. baluensis* n. sp.

Recent studies of the *akamushi*-group have shown that the ratio PW/Coxa-II (see fig. 76) gives a valuable and apparently reliable means of separating *T. deliensis* from *T. akamushi*. In a number of series of *T. deliensis*, this ratio averaged 1.16 and was consistently well below 1.30, while in *T. akamushi* taken from many different sources it ranged between 1.30 to 1.50 (mean 1.40). Further details of this study are being made the subject of a paper now in preparation. Use is made of the PW/Coxa-II ratio in a following study by Traub and Evans (1953, this *Study*, p. 89).

STANDARD MEASUREMENTS IN MICRONS, *T. deliensis* from Borneo.

			AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	$\frac{PW}{Cox\ II}$	$\frac{PW}{SD}$	$\frac{PW}{ASB}$	$\frac{PW}{A-P}$
Mean	...	...	55	68	26	24	15	32	46	57	53	54	$\frac{66}{57}$ =1.16	1.65	2.8	2.0
Range (+ or -)	...		6	7	3	3	2	3	4	5	4	4	0.07	0.07	0.05	0.03

Records.—*T. deliensis* has been taken by us on Mt. Kinabalu from the following hosts : 1) at Tenompok, at an elevation of about 4,500 feet on *Rattus rattus diardii*, *Rattus exulans*, *Callosciurus lowii*, *Nannosciurus whiteheadi*, *Dremomys everetti*, *Crocidura* sp., *Hylomys suillus*, *Tupaia minor*, and *Tupaia montana*. 2) At Lumu Lumu, elevation 6,300 feet, on *Rattus whiteheadi*. 3) At Kamborangah in moss-forest, elevation 7,800 feet, on *Tupaia montana* and *Dendrogale melanura baluensis*. *T. deliensis* was also found in numbers on a variety of hosts in the coastal collections near Menggatal and Beaufort as well as in Sarawak.

Trombicula (Leptotrombidium) akamushi Brumpt, 1910 (figs. 79-86, pp. 70, 71).

Diagnosis of Larva.—Closely resembling *T. deliensis* but the PW/Coxa-II ratio ranges between 1.30-1.50 ; there are usually 35-40 dorsal setae, commencing as a rule 2.10.8., but Kinabalu specimens frequently are 2.8.6. PW typically is over 72 ; and the sensillae bases are usually clearly inserted well anterior to the line of PLs.

On Kinabalu, we have collected typical *T. akamushi* from chicks of an unidentified ground bird, from *Macaca irus* and the tree shrew, *Tupaia minor*, at Tenompok, from *Rattus rattus diardii* in the vicinity of Bundu Tuhan, elevation 4,000-5,000 feet, and from *Tupaia montana* at Kamborangah, elevation 7,800 feet ; but not from the coastal collections. No specimens of *T. akamushi* have been found in the considerable collections from Sarawak made in collaboration with Mr. Tom Harrisson.

A form with dorsal setae generally 2.8.6., resembling *T. akamushi* f. *obscura* of Womersley, was widespread and common. Comments on this form are being withheld pending further detailed studies of the larvae and nymphs.

Comparative Measurements, Ratios and Diagnostic Characters for Ten Species of *Trombicula* from North Borneo.

	<i>T. flagellifera</i> sp. nov.	<i>T. tuhana</i> sp. nov.	<i>T. vorca</i> sp. nov.	<i>T. (L.) baluensis</i> sp. nov.	<i>T. (L.) pipellae</i> sp. nov.	<i>T. (L.) pilalta</i> sp. nov.	<i>T. (L.) tarsala</i> sp. nov.	<i>T. (L.) deliensis</i> T. (L.)	<i>T. (L.) akamushi</i> T. (L.)	<i>T. (L.) micula</i> sp. nov.
1. Palpal formula ...	N/N/NNN	N/N/NNN	B/B/NNb	N/N/BNN	N/N/BNN	N/N/BNN	N/N/BNN	N/N/BNN	N/N/BNN	N/N/BNN
2. Palpal claw, prongs ...	3	3	3	2	2	2	3	3	3	3
3. Special features*	A	AB	—	—	—	—	C	—	—	—
4. AW	72	59	82	63	80	84	59	55	69	56
5. PW	79	65	93	79	93	97	68	68	77	62
6. SB	26	26	28	35	32	39	27	26	33	29
7. ASB	31	21	40	28	39	38	28	25	25	19
8. PSB	12	10	17	15	15	15	11.5	15	14	12
9. A-P	31	23	42	30	38	33	26.5	32	27	20
10. AL	54	31	66	54	61	54	43.5	46	39	28
11. AM	52	33	59	54	89	87	68.5	57	50	35
12. PL	68	55	80	61	126	76	67.5	53	51	42
13. DS length	60	49	62	59	91	65	62.5	54	49	39
14. PW/Coxa II	1.1	1.2	1.20	1.28	1.15	1.35	1.21	1.16	1.40	1.27
15. PW/SD	0.06	0.05	0.05	0.05	0.05	0.06	0.01	0.07	0.10	0.05
16. PW/ASB...	1.8	2.1	1.6	1.85	1.7	1.8	1.78	1.65	2.00	2.0
17. PW/A-P...	0.1	0.07	0.04	0.07	0.05	0.1	0.03	0.07	0.08	0.06
18. PW/SD	2.52	3.07	2.3	2.8	2.38	2.53	2.5	2.8	3.10	3.1
19. AM/SD	0.08	0.08	0.03	0.1	0.07	0.018	0.01	0.05	0.11	0.09
20. No. DS	2.4	2.8	2.2	2.6	2.44	2.9	2.6	2.7	2.9	3.1
21. Rows DS	0.03	0.07	0.08	0.05	0.05	0.05	0.1	0.03	0.05	0.02
	1.6	1.8	1.4	1.4	2.86	1.43	1.71	1.33	1.30	1.35
	1.10	0.1	0.7	0.8	0.12	0.06	0.01	0.07	0.08	0.01
	1.2	1.1	1.03	1.25	2.0	1.64	1.73	1.44	1.28	1.13
	0.01	0.1	0.08	0.8	0.10	0.07	0.01	0.05	0.08	0.01
	28-32	30	52-62	40-55	26-28	38-42	26	28	35-42	28
	2-8-6	2-8-6	6(8)-10-12	2-10-10	2-6-6	2-10-10	2-6-6	2-8-6	2-10-8	2-8-6

*A With mastifemorala III, and long or medium nude setae on tibia and genu III. B Only anterior eye apparent. C With very large tarsalae (spurs) I and II.

Acknowledgements

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Summary

Eight new species of *Trombicula* from North Borneo are described and figured. Of these, *Trombicula flagellifera* and *T. tuhana*, from Mt. Kinabalu, have a palpal formula N/N/NNN and possess mastifemoralae on Leg III. *Trombicula vorca*, from a bird on Kinabalu, with very large eyes and a palpal formula B/B/NNb, is one of a group with *T. corvi* Hatori, *T. densipiliata* Walch, and *T. nissani* Dumbleton.

The remaining five species are all in the subgenus *Leptotrombidium*: (1) *T. (L.) baluensis*, from true shrews and gymnures on Kinabalu, and characterized by very heavy subpectinate bristles. (2) *T. (L.) pipellae*, on Kinabalu rodents and viverrids, with extremely long posterolateral setae, a PW of over 90 μ and a 2-pronged palpal claw. (3) *T. (L.) pilalta* from *Rattus* and tree shrews on Kinabalu above 7,000 ft. elevation, with an exceptionally long AM seta, 3-pronged palpal claws, and PW a over 91 μ . (4) *T. (L.) micula*, very close to *T. (L.) deliensis* with a smaller and less deep scutum, from *Nannosciurus* and other squirrels near Kuching, Sarawak. (5) *T. (L.) tarsala*, also from Kuching, unique in that the tarsala on leg I and II is as long as the tarsus is broad at this point.

The vectors, *T. (L.) deliensis* Walch and *T. (L.) akamushi* Brumpt are redescribed in so far as is necessary for comparisons with the above species and for purposes of fresh locality and host records. A means of differentiating these two species by means of the PW/Coxa-II ratio is offered.

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MALAYSIAN PARASITES V

SPECIES OF *EUSCHÖNGASTIA* SENSU LATO (ACARINA TROMBICULIDAE) FROM BORNEO

By

ROBERT TRAUB AND J. R. AUDY

This paper describes the larvae of six new species of *Euschöngastia* Ewing, 1938. Five of these were collected by the joint U.S. Army and Colonial Office research units on Mt. Kinabalu, and the sixth was collected both in Sarawak (in collaboration with Mr. Tom Harrisson) and in the Kinabalu and Beaufort areas of North Borneo. The circumstances of the collections have been described in the previous paper (Traub and Audy, 1953, this *Study*, p. 45). As in other papers of this series, a species is first described in detail and only salient differences are described for subsequent closely-related species.

The genus *Euschöngastia* is here taken in a broad sense to include the *oudemansi*-group placed in the genus *Walchiella* by Fuller, 1952. Chiggers of this genus are important and very abundant parasites of rodents, and it is to be expected that at least some of them are of medical significance. This is supported, for example, by the isolation by Traub *et al.* (1950) of the rickettsiae of scrub typhus from a species of *Euschöngastia* subsequently described as *E. audyi* (Womersley, 1952)*. The chiggers had been collected from a squirrel in the primary forest in Malaya. Gispén, also in 1950, reported the isolation of the rickettsiae of murine typhus from *E. indica* (Hirst, 1915) in Indonesia. Although no New World species of *Euschöngastia* is definitely known to bite man, various species may be responsible for transmission of infections among their animal hosts, and thus be of considerable indirect medical importance.

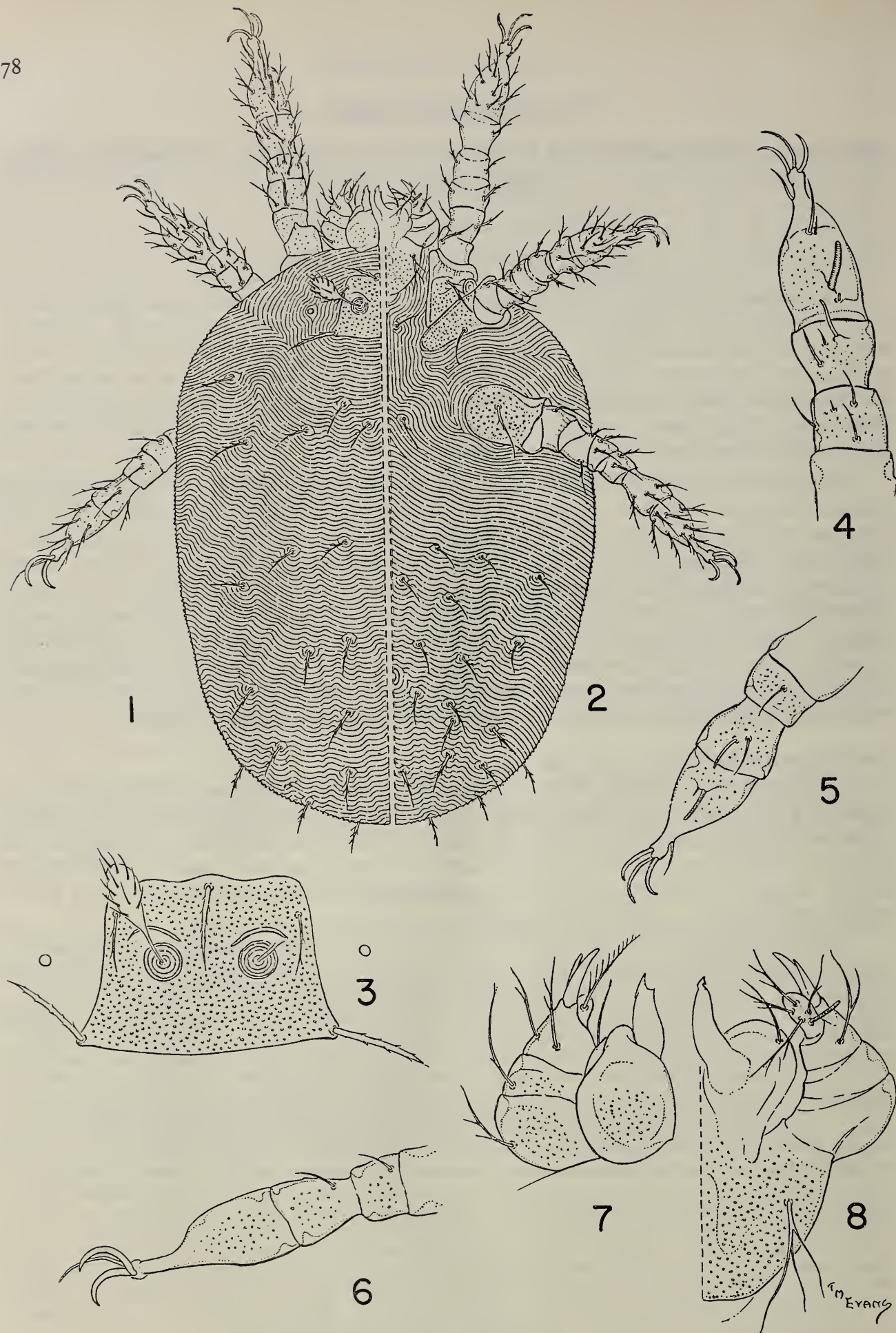
Euschöngastia indicella n. sp. (figs. 1-8).

Diagnosis of larva.—In the *E. indica* group, and close to *E. labuanensis* Womersley, 1952 in having a very small scutum, but separable from it in that the posterior margin of the scutum in the new species is slightly convex, not concave (PSB 20 or more, not 11), the ALs are relatively quite removed from the anterior margin (closer to margin of sensillary bases than to anterior margin of scutum) instead of being submarginal; there are only about 30-34 dorsal setae, arranged 2.8.6...., instead of 62 arranged 2.10.10.10....

Description of Larva.—*Body:* Subovate, about $250 \times 185\mu$ when slightly engorged. Eyes apparently $1+1$, about 4.5μ in diameter; slightly closer to level of AL than PL. *Gnathosome:* Chelicerae each about three times as long as broad at base; lacking dorsal teeth, with a small subapical medial and also lateral tooth forming characteristic tricuspid cap. Palpal coxae and femora punctate. Palpal setal formula $b(N)/b/bbb+$; the degree of fraying rather variable but setae usually with 1-3 short barbules. Palpal tarsus with a basal striated rod and about 5 bristles, most of these branched. Palpal claw 2-pronged, medial prong somewhat longer than lateral. Galeal seta N (i.e. nude). Palpal coxal seta with 3 branches. *Scutum:* very small (PW less than 50μ); about three-fourths as long as broad at maximum; somewhat trapezoidal, but anterior margin not much shorter than posterior margin, lateral margins slightly concave; anterior margin almost straight; posterior margin slightly convex, almost straight, but laterally mildly sinuate. Scutal setae short, none equal to half of PW; barbs very short so that setae appear tomentose or roughly pubescent. With distinct ridges anterior to sensillary bases. Sensillae clavate; clothed with long spicules (5μ). AL setae displaced caudad, nearer to the sensillary ridge than to anterior margin.

Body Setae: Dorsal setae similar to scutal setae; about 32-34 in number, usually arranged 2.8.6.6.4.4(2).2. With about 30-34 ventral setae, of which about 12 are postanal (caudal setae). True ventral setae about $12-14\mu$, distinctly branched and apically more acuminate than are the caudals and true dorsals. *Legs:* Coxae and legs punctate. All coxae unisetose, the setae slender and with inapparent branches. Seta on coxa II nude; others resembling the pair of sternal setae between junction of coxae I and II and the sternal pair between coxae III. Seta on coxa III midway between midpoint and anterior margin. Posterior

* This species was originally cited as *E. indica*. Since then this chigger, which is a dominant and characteristic parasite of tree-living mammals in the Malayan forests, has been identified with *E. audyi* described by Womersley in 1952 from material from South Burma (*J.R.A. coll.*, viii. 1945). It is also present in North Borneo and Sarawak.



Euschöngastia indicella n. sp.

	Dorsum and Venter of Larva	I, 2	
Scutum	3	Mouthparts, Dorsal	7
Legs I, II, III	4, 5, 6	Ventral	8

margin of coxa II weakly sclerotized. Sensory setae as follows: Leg I, 3 genualae and a microgenuala; 2 tibialae and a microtibiala; a microtarsala (microspur) immediately proximal to a well-developed tarsala (spur), subterminala and short parasubterminala, a pretarsala. Leg II: a genuala; 2 tibialae; microtarsala anterior and close to tarsala; a pretarsala. Leg III: a genuala and a single tibiala. Middle tarsal claw slightly longer than others.

STANDARD MEASUREMENTS IN MICRONS, *E. indicella* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	PW Coxa II	PW ASB	PW A-P	ASB SB-AL†
Holotype ...	33	47	18	15	18	22	13	19	22	18	47/36 =1.30	3.1	2.14	16/8 2.0
Paratypes (20) Mean	31	45	16	14	20	21	13	20	23	19	1.25	3.2	2.14	1.83
Range (+ or -)	2	4	3	3	3	2	2	2	3	3	0.06	0.08	0.23	0.18

Type Material.—Holotype and 20 paratypes ex *Chiropodomys legatus* (a small rat living in internodes of bamboo), North Borneo, Mt. Kinabalu, Bundu Tuhan, elev. 5,000 feet, 31. vii. 1951 (R. Traub). Holotype (U.S.N.M. 2111) and 3 paratypes in collections of U.S. National Museum. Paratypes in collections of British Museum, Rocky Mountain Laboratory, the South Australian Museum, Chicago Natural History Museum, other institutions, and the authors' collections.

Euschöngastia roluis n. sp. (fig. 9-16, p. 80).

Diagnosis of Larva.—Near *lorius* (Gunther, 1939) but distinguishable as follows: Leg III with a genuala, a tibiala but no sensory setae on tarsus, instead of Leg III possessing *only* a tarsala, and that conspicuous. Further separable in that the eye is reduced to a small single structure, instead of being double and on an ocular plate. With palpal claw normal, about 12 μ in length; not stumpy, only about 7 μ . Separated from *E. indicella* n. sp., in that the scutum is larger (PW 59 not 48); the AM and PL scutal bristles are longer than half the breadth of the scutum, not less than half as long, and the dorsal bristles are about 22-26 in number, arranged 2-6-4...; instead of 32-34 arranged 2-8-6...; PSB subequal to ASB, instead of definitely greater.

STANDARD MEASUREMENT IN MICRONS, *E. roluis* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	DS	PW Coxa II	PW ASB	PW A-P	ASB SB-AL
Holotype ...	43	59	18	23	23	23	21	28	35	26	59/51 =1.16	2.56	2.26	23/13 =1.8
Paratypes (14) Mean	43	59	19	23	22	25	21	31	35	29	1.13	2.56	2.28	1.8
Range (+ or -)	4	4	2	2	2	2	2	3	4	3	0.06	0.04	0.04	0.06

Description of Larva.—The following description is in comparison with *E. indicella*. Partially engorged larve about 600 $\times$ 350 μ . Eyes reduced 1+1, 5.4 μ in diameter, midway between AL and PL but placed well to the side at a distance from scutum subequal to AP. *Gnathosome*: Palpal formula b/(B)/bbb, but degree of fraying variable, branches usually limited to 2-3 in number. Palpal claw 2-pronged, as in *indicella*. *Scutum*: Much as in preceding species in shape but larger, and posterior margin sinuate. PL and AM scutal setae only slightly shorter than depth of scutum. Bases of AL setae as close to sensillary ridge as to anterior margin. *Body Setae*: Dorsal setae similar to scutal setae but barbs perhaps slightly more apparent even though inconspicuous; about 22-26 in number arranged 2.6.4.4.4. (2)-2(0). Ventral setae about 12-16, 24 μ long, almost nude, plus 8-12 postanals essentially resembling dorsals. True ventrals only about 24 μ long, scarcely barbed, almost nude. *Legs*: Agrees with *indicella* n. sp. in that seta on coxa II is nude; those on other coxae with but 2 or 3 short branches. Coxae II and III with posterior margins very weakly sclerotized. Sensory setae as in *indicella* but apparently lacking a microtarsala II.

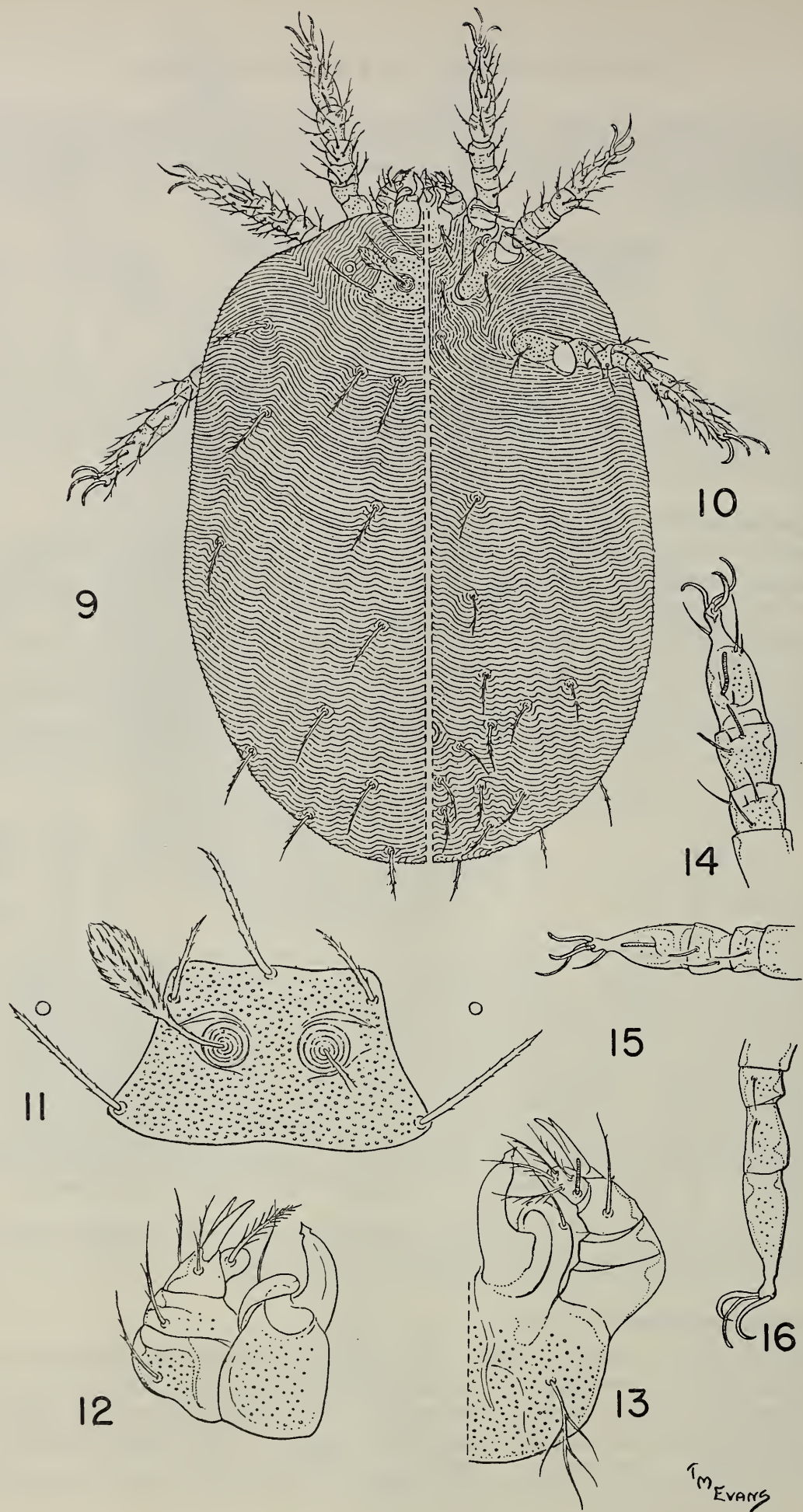
Type Material.—Occurred with *E. indicella* on *Chiropodomys legatus*, Mt. Kinabalu, Bundu Tuhan, elev. 4,000 feet, 31. vii. 1951 (R. Traub). Holotype (U.S.N.M. 2112) and 3 paratypes in U.S. National Museum. Eleven Paratypes, *ibid.*, distributed as for preceding species.

Euschöngastia ocellifera n. sp. (fig. 17-24, p. 82).

Diagnosis of Larva.—Near *E. roluis* n. sp. but distinguishable in that the eyes are not reduced but are of the normal paired type and inserted on an ocular plate; with a 3-pronged palpal claw, not 2-pronged; with the AL setae more caudally displaced, at level of the sensillary ridge instead of midway between ridge and anterior margin, so that distance from to AL lines

† In the palpal formula, b indicates a slightly barbed or almost nude seta, as contrasted with B which indicated a typically barbed seta; b(N) signifies that the seta may also appear to be nude.

‡ SB-AL is distance from SB to AL



EVANS

Euschöngastia roluis n. sp.

Scutum	Dorsum and Venter of Larva	9, 10	
Legs I, II, III	11	Mouthparts, Dorsal	12
	14, 15, 16	Ventral	13

is 9μ , not 13-15 as in *roluis*. Scutum produced into "shoulders" at insertion of AL setae instead of being merely rounded. Posterior margin of scutum more sinuate than in *roluis* (cf. fig. 11). Scutum with rather pronounced ridges posterior to sensillae bases; these absent in *roluis*.

Description of Larva.—*Body*: Subovate, about $364 \times 225\mu$ in somewhat engorged holotype. Eyes distinct 2+2 on ocular plate, anteriormost somewhat the larger; posterior eye in a line with PL. *Gnathosome*: Chelicers and lateral tooth as in preceding species. Palpal formula b/b/bbb, each seta slightly variable regarding degree of fraying, but with only one or two branches. Palpal claw with medial prong longest, lateral prong one-half to two-thirds as long, middle prong intermediate. *Scutum*: Fairly large; seven-eighths as long as broad; anterior margin somewhat sinuate, the convexity median; posterior margin more sinuate, the medial portion concave; with "shoulders" at PL, but remainder of lateral margins slightly convex. AM seta about half length of scutum. AL setae displaced caudad to a level midway between SB and anterior margin of scutum; less than one-third length of scutum. PL setae nearly three-fifths length of scutum. All scutal setae with barbs inapparent, short. *Body Setae*: Dorsal setae similar to scutal setae, about 24-26 arranged typically 2.6.6.4.4.2. Ventral setae about 12, 19μ long, plus 10-12 postanals. *Legs*: essentially as in *E. indicella* n. sp., including sensory setae.

STANDARD MEASUREMENTS IN MICRONS, *E. ocellifera* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	D.S	PW Coxa II	PW SD	PW ASB	PW A-P	ASB SB-AL
Holotype ...	45	56	21	21	22	21	16	29	33	31	56/45 =1.24	1.3	2.7	1.3	2.3
Paratypes (3)															
Mean ...	44	56	21	21	21	21	16	28	32	32	1.22	1.33	2.7	1.3	2.3
Range (+ or -)	1	2	1	2	2	2	1	2	3	3	0.04	0.04	0.05	0.04	0.02

Type Material.—Holotype and two paratypes on *Chirodomys legatus*, Mt. Kinabalu, Tenompok, elev. 4,500 ft., viii. 1951 (R. Traub). Holotype (U.S.N.M. 2113) in U.S. National Museum. Others in authors' collections.

***Euschöngastia daria* n. sp. (figs. 25-30 and 33-35, p. 83).**

Diagnosis of Larva.—Close to *E. audyi* Womersley, 1952, but separable as follows: With only one pair of sternal setae between coxae III; not two. Tarsus III with but one mastitarsala (fig. 29) instead of two, one of which is ventral (cf. fig. 32, *E. audyi*). Tibia III bearing only one sensory seta (fig. 29) lacking the two subflagellate setae of *E. audyi* (fig. 32). Leg setae relatively stout, freely branched, subpectinate at base (fig. 33); in *E. audyi* these setae are fine, long, and with short inconspicuous branches (fig. 31).

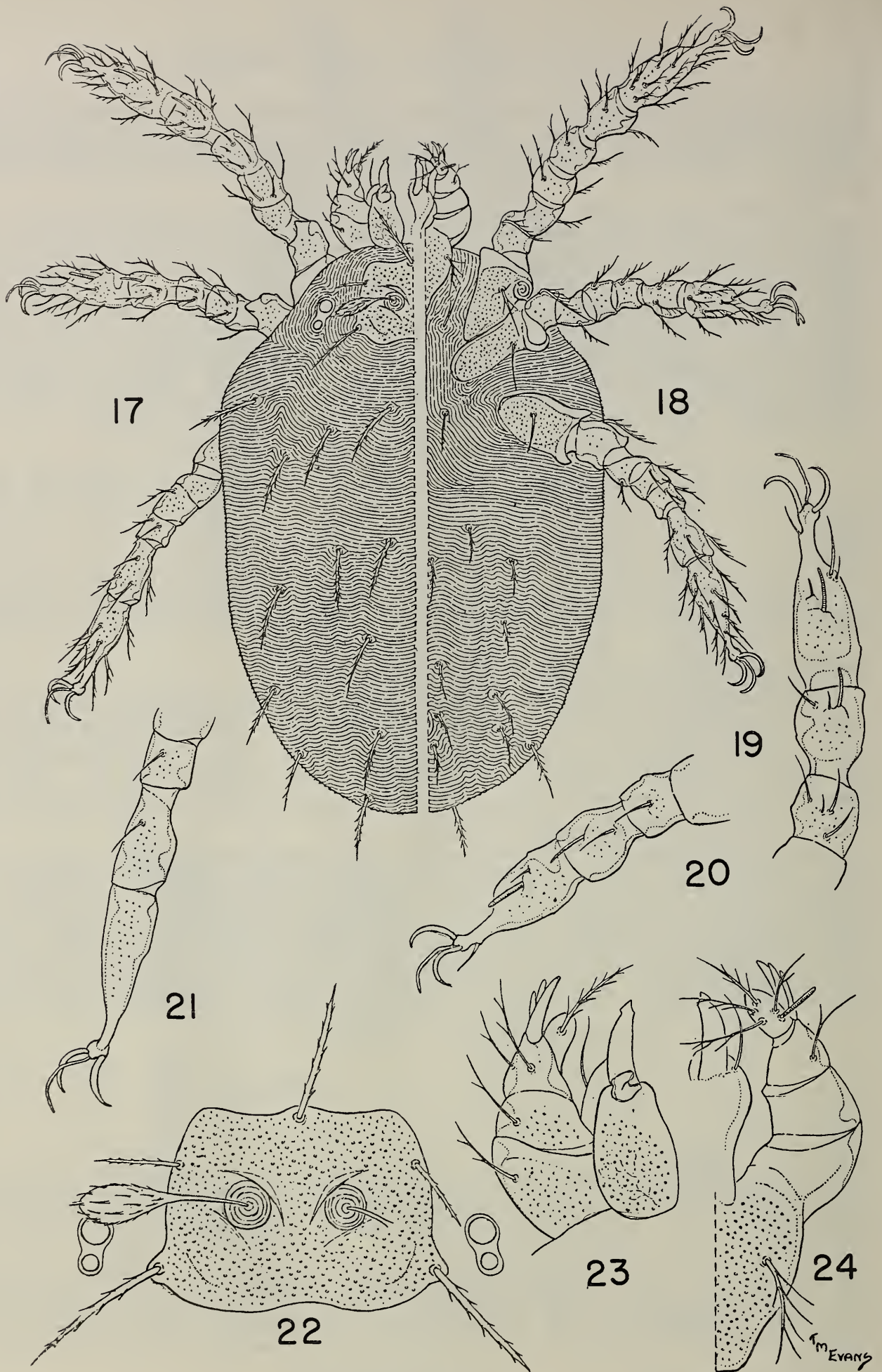
Description of Larva.—*Body*: Subovate, about $355 \times 255\mu$ in rather engorged holotype. Eyes 2+2 on ocular plate, fairly close to base of PL; anterior eye somewhat the larger. *Gnathosome*: Chelicers about four times as long as broad at base; with tricuspid cap of genus. Palpal formula B/b/Nbb. Palpal claw 2-pronged, medial prong the longer and stouter. Maxillary seta fairly plumose. *Scutum*: Almost as long as broad at level of sensillary bases. Somewhat rectangular but caudal margin rather convex; anterior margin slightly sinuate; lateral margins shallowly concave. AL setae somewhat displaced caudad, but much closer to anterior margin than to sensillary ridges. With 'shoulders' at PL bases. Sensillary bases at midline of scutum. Scutal setae with short barbs; AL about $1/2$ length of scutum; AM about $2/3-3/4$ length of dorsal plate; PL slightly longer than AM. *Body Setae*: Dorsal setae similar to scutal

STANDARD MEASUREMENTS IN MICRONS, *E. daria* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	D.S	PW Coxa II	PW ASB	PW A-P	ASB SB-AL
Holotype ...	51	69	28	24	26	28	21	—	39	32	69/51 = 1.38	2.9	2.46	24/16 = 1.5
Paratypes (7) Mean	51	70	27	23	24	26	22	34	38	37	1.37	3.0	2.54	1.6
Range (+ or -)	3	5	3	3	2	3	2	4	5	4	0.06	0.07	0.08	0.10

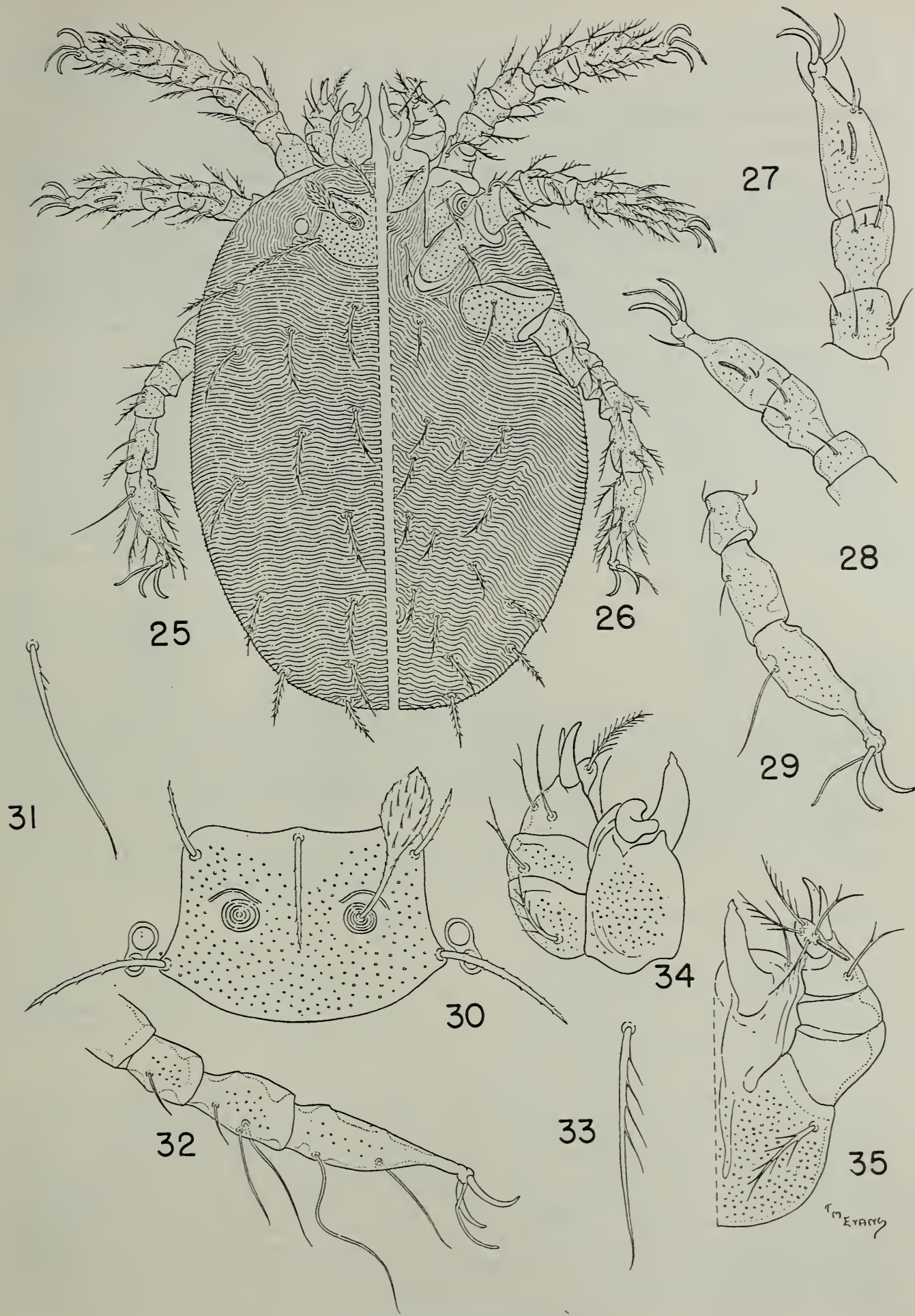
setae; about 24-26 usually arranged 2.6.6.4.4.2. Ventral setae about 16, 21μ long, lightly plumed plus about 12 postanal (caudal) setae. *Legs*: Non-sensory setae all subpectinate or with distinct branches, but with a definite tendency for distal third to be simple and slender. Sensory setae as follows: Legs I and II as in *E. indicella* n. sp. Leg III with the usual single genuala and tibiala but in addition with a long mastitarsala.

Type Material.—Holotype from a chick of an unidentified ground bird, Mt. Kinabalu, Tenompok, elev. 4,500 ft., 28. vii. 1951 (R. Traub). Paratypes from same locality as follows: 4 ex *Tupaia montana baluensis*, a tree shrew, 16 & 17, vii. (R. Traub & J. R. Audy), 1 ex *Tupaia m. minor*, 3, viii. *ibid*; 2 ex *Nannosciurus whiteheadi*, loc. cit. 17vii (R. Traub and J. R. Audy); and one ex *Rattus whiteheadi*, *ibid* but 23. vii. Holotype (U.S.N.M. 2114) in U.S. National Museum, paratypes in U.S.N.M. and authors' collections.



Euschöngastia ocellifera n. sp.

Scutum	Dorsum and Venter of Larva	Mouthparts, Dorsal	17, 18	23
Legs I, II, III	22	Ventral	19, 20, 21	24



Euschöngastia daria n. sp.

Scutum	Dorsum and Venter of Larva	25, 26	
Legs I, II, III	30	Mouthparts, Dorsal	34
	27, 28, 29	Ventral	35
	Typical subpectinate leg-seta	33	
<i>Euschöngastia audyi</i> Womersley, 1952			
Typical leg seta	31	Leg III	32

Euschöngastia (Walchiella) calunosa n. sp. (figs. 36-45).

Diagnosis of Larva.—In the segmentation of the legs (legs II and III 6-segmented) and in general characters, *E. calunosa* n. sp. is close to *E. oudemansi* (Walch 1922), *E. lewthwaitei* (Womersley 1952) and *E. traubi* (Womersley 1952) which are members of the genus *Walchiella* Fuller 1952, recognised by us provisionally as a subgenus of *Euschöngastia* sensu lato. The new species is distinguishable from *E. traubi* in having the dorsal setae arising from normal if well-chitinised bases and not from platelets. It is distinguishable from *E. oudemansi* in having non-toothed chelicers, from both *E. oudemansi* and *E. lewthwaitei* in the shape and size of the large scutum, and further from *E. lewthwaitei* in having only 28 dorsal setae instead of 42.

Description of Larva.—*Body*: Subovate, about $450 \times 290\mu$ in fairly engorged specimen. Eyes $2+2$ on ocular plate, anteriormost somewhat the larger. *Gnathosome*: Chelicers 3-4 times as long as broad at base; tricuspid cap prominent. Palpal formula N/b(3-4)/bbb, the sparsely branched setae with 2-6 branchlets. Palpal claw 3-pronged but innermost ventral quite short, inapparent from dorsal aspect. Galeal seta nude. Palpal coxal seta well-plumed. *Scutum*: About 1.6 times as broad as long; anterior margin doubly but shallowly sinuate, the convexity median; lateral margins somewhat concave except at broadly rounded shoulders, especially near insertion of PL bristles; narrowing from rear to front; caudal margin sinuate, biconvex, the concavity median. Almost entirely punctate. Sensillae inserted slightly nearer posterior margin than anterior margin; with distinct ridges anterior to bases. Sensillae fusiform, about $58 \times 9.5\mu$ (including petiolate base), setules dense, relatively long (5μ), AM seta submarginal; slightly more than $2/3$ depth of scutum (SD) and a trifle longer than ALs. PLs somewhat less than half scutal depth. The scutal bristles densely clothed but the branches so short and appressed as to be inapparent.

STANDARD MEASUREMENTS IN MICRONS, *E. calunosa* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	D.S	PW Coxa II	PW ASB	PW A-P	PSB SB-PL*
72	72	100	43	32	28	42	40	47	30	57	100/70 =1.43	3.1	2.37	28/11 =2.5
Paratypes (10) Mean	71	100	43	33	28	42	42	49	30	58	1.42	3.0	2.37	3.3
Range (+ or -) ...	6	6	3	2	2	3	4	5	3	5	0.05	0.15	0.08	0.8

Body Setae: Setal bases rather prominent (fig. 39, dorsal seta, and fig. 40, ventral) well sclerotized. Dorsal setae pinnatifid, often subpectinate, the branchlets fairly long and well separated; apical fifth of bristle usually nude, acuminate; those near midline longer (about 57μ) lateral setae shorter (to 45μ), about 28-30, irregular due to displacement of lateral setae to points between rows, i.e. 2.6.4.4.6.4.2(2). Ventral setae 42-48, about 19μ , subpectinate, pinnatifid, plus about 16 postanals caudal setae. *Legs*: Seta on each coxa plumed, well developed. Posterior margins of coxae relatively well sclerotized (cf. *E. indicella*). Sensory setae of legs as in *E. indicella* n. sp.

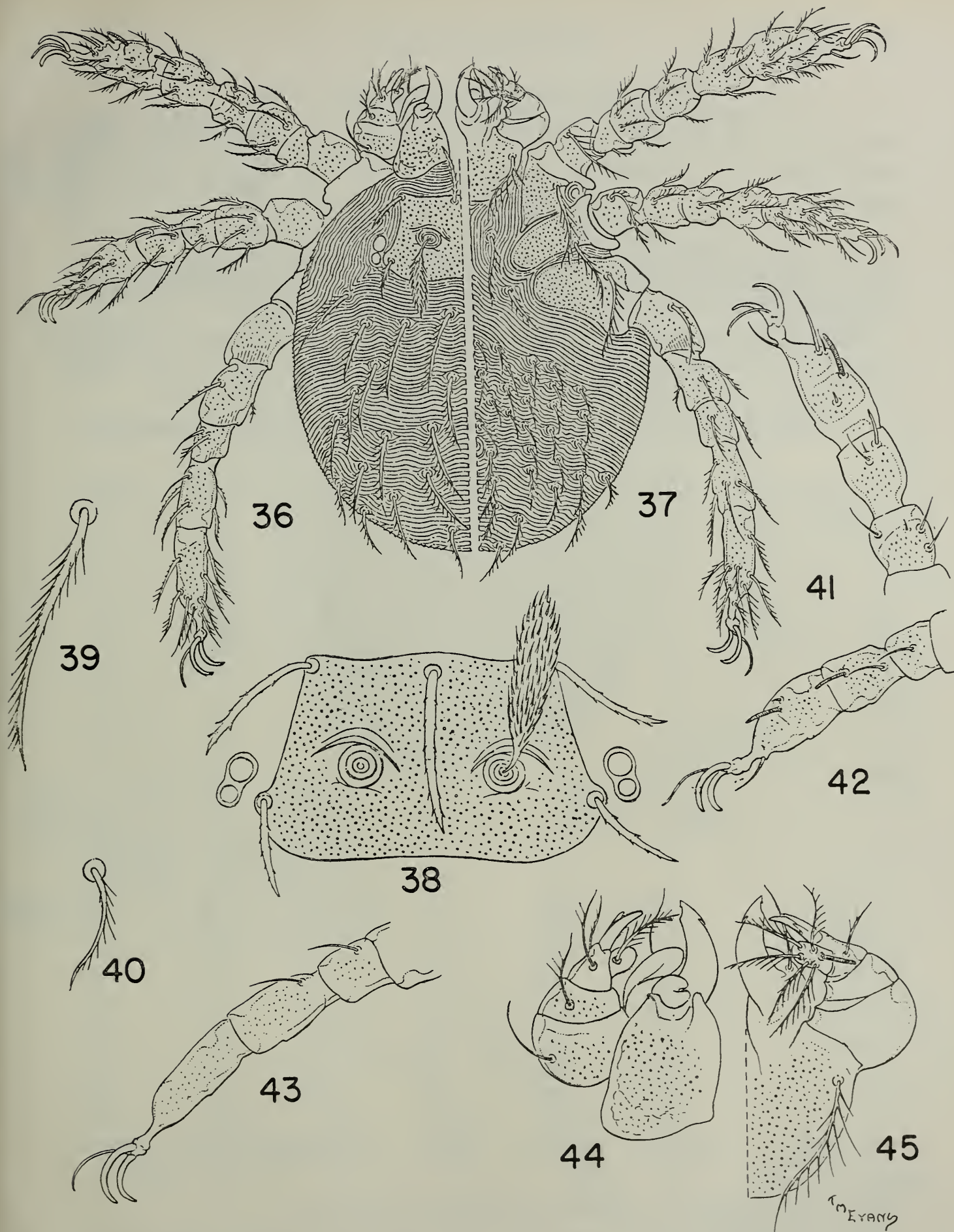
Type Material.—Holotype and 25 paratypes ex *Rattus rattus baluensis*, a densely furred rat of the uppermost reaches of Mt. Kinabalu; Kamborangah, elev. 7,800 ft., 26. vii. 1951 (*R. Traub*). Holotype (U.S.N.M. 2115) in U.S. National Museum. Paratypes distributed as for *E. indicella* sp. nov.

Euschöngastia (Walchiella) asonluca n. sp. (figs. 46-53, p. 87).

Diagnosis of Larva.—Separable from *E. calunosa* n. sp. in the small and differently shaped scutum; PW/coxa-II ratio about 1.2, not 1.42; and in the relatively smooth dorsal setae, not pinnatifid. Separable from *E. lewthwaitei* in the smaller scutum, and in having 28 instead of 42 dorsal setae, and separable from all other members of the subgenus *Walchiella* in the second dorsal seta of the first row being about twice as long as the others.

Description of Larva.—*Body*: Subovate, about $163 \times 238\mu$ in somewhat engorged holotype. Eyes $2+2$ on ocular plate. *Gnathosome*: Chelicers rather broad, slightly less than three times as long as broad at base. Palpal formula N/N/NNb. Palpal claw 2-pronged, medial prong the longer. Palpal coxal seta plumose. *Scutum*: Somewhat trapezoidal, well chitinised, about 1.4 times as broad (at maximum) as long. Anterior and posterior margins slightly sinuate; lateral margins slightly convex, sloping forwards. Scutal setae with branchlets closely appressed to axis, appearing simple; short; (AM missing in all specimens examined); AL slightly longer than PL setae; AL about one-half depth of scutum. ALs submarginal; PLs somewhat displaced forward, away from caudal margin. Sensillae clavate, with distinct petiolate base, $40 \times 17\mu$ with well-separated spicules about 5μ . *Body Setae*: Dorsal setae resemble scutal seta in that branchlets are usually inapparent; unusual in that second bristle (on each side) of first row typically twice as long as other setae. DS about 28, arranged 2.6.6.2.6.... the rest irregular; Ventral setae 22-24, 16μ , minutely serrate, plus 12-14 caudal setae. *Legs*: Coxal setae thinly plumed. Posterior margins of coxae fairly well sclerotized. Sensory setae of legs as in *E. indicella* n. sp.

* SB-PL is distance from SB to PL.



Euschöngastia (Walchiella) calunosa n. sp.

Scutum	38	Mouthparts, Dorsal	44
Dorsal and Ventral Seta	39, 40	Mouthparts, Ventral	45
Legs I, II, III	41, 42, 43		

STANDARD MEASUREMENT IN MICRONS, *E. asonluca* n. sp.

	AW	PW	SB	ASB	PSB	A-P	AL	AM	PL	D.S†	PW Coxa II	PW ASB	PW A-P	PSB SB-PL
Holotype ...	50	67	33	26	23	32	23	—	16	23.47	67/56 = 1.20	2.57	2.1	23/12 = 1.9
Paratypes (5) Mean	51	68	31	25	23	33	25	—	16	21.50	68/57 = 1.18	2.72	2.06	2.1
Range (+ or -)	2	3	2	2	2	2	3	—	3	4-5	0.05	0.2	0.8	0.25

† Second seta in first row usually twice as long as others.

Type Material.—Holotype and 6 paratypes ex *Tupaia tana*, Sarawak, Kuching, fifth mile, Stapok Road Forest Reserve, coll. jointly with Sarawak Museum, 4. ix. 1951. (Tom Harrison and M. Nadchatram). Holotype (U.S.N.M. 2116) and one paratype in U.S. National Museum, remaining paratypes in collections of British Museum, South Australian Museum, and author's collections.

Remarks.—A large number of specimens have been provisionally identified as this species in material from Sarawak, North Borneo, and Malaya. A further series of a very closely similar form but with subequal dorsal setae has also been set aside for further study.

**Comparative Measurements and Data of six Species of Borneo Chiggers
of the Genus *Euschöngastia*.**

Species	<i>indicella</i> n. sp.	<i>roluis</i> n. sp.	<i>ocellifera</i> n. sp.	<i>daria</i> n. sp.	<i>calumosa</i> n. sp.	<i>asonluca</i> n. sp.
AW (mean) ...	31	43	44	51	71	51
(range)	2	4	1	3	6	2
PW ...	45	59	56	70	100	68
	4	4	2	5	6	3
SB ...	16	19	21	27	43	31
	3	2	1	3	3	2
ASB ...	14	23	21	23	33	25
	3	2	2	3	2	2
PSB ...	20	22	21	24	28	23
	3	2	2	2	2	2
A-P ...	21	25	21	26	42	33
	2	2	2	3	3	2
AL ...	13	21	16	22	42	25
	2	2	1	2	4	3
AM ...	20	31	28	34	49	—
	2	3	2	4	5	—
PL ...	23	35	32	38	30	16
	3	4	3	5	3	3
DS ...	19	29	32	37	58	21&50
	3	3	3	4	5	4 - 5
PW/Coxa II...	1.25	1.13	1.22	1.37	1.42	1.18
	0.06	0.06	0.04	0.06	0.05	0.05
PW/ASB ...	3.2	2.56	2.7	3.00	3.0	2.72
	0.08	0.04	0.05	0.07	0.15	0.2
PW/A-P ...	0.14	2.28	1.3	2.54	2.31	2.06
	0.23	0.04	0.04	0.08	0.08	0.8
ASB/SB-AL*	1.83	1.8	2.3	1.6	1.13	1.24
	0.18	0.06	0.02	0.10	0.07	0.17
PSB/SB-PL†	1.34	2.13	2.08	2.77	3.3	2.1
	0.20	0.49	0.25	0.21	0.8	0.25
PW/SD ...	1.42	1.34	1.33	1.46	1.56	1.39
	0.08	0.06	0.04	0.19	0.16	0.05
Eyes ...	single	single	double	double	double	double
Palpal formula ‡	b(N)/b/bbb	b(B)/b/bbb	b/b/bbb	B/b/Nb	N/b(3-4)/bbb	N/N/NNb
Dorsal setal rows	2-8-6...	2-6-4...	2-6-6...	2-6-6...	2-6-4...	2-6-6
Mastitarsala III	0	0	0	+	0	0

* SB-AL is distance from SB to AL, measured from SB to imaginary line connecting ALs.

† SB-PL—as above, but for PL.

‡ b indicates a slightly barbed or frayed or virtually nude seta, as contrasted with B which indicates a typically barbed seta.

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We are indebted to Miss Mary Lou Morrow, Department of Entomology, Army Medical Service Graduate School, for critical review of the manuscript, to Mr. T. M. Evans of that Department, for preparing the illustrations; and to Mr. H. Womersley for very kindly sending us a series of *E. asonluca* n. sp. which he had studied and described in draft manuscript. The greater part of the joint investigation of potential vectors in North Borneo was supported by the Commission on Immunization of the U.S. Armed Forces Epidemiological Board.

Summary

Six new species of the Trombiculid genus *Euschöngastia*, all from Borneo, are described and illustrated. *E. indicella*, *E. roluis*, and *E. ocellifera*, from *Chiropodomys*, and *E. daria*, from a variety of hosts, are in the *E. indica* group and were collected on Mt. Kinabalu. The two other new species *E. calunosa*, from *Rattus rattus* subspecies on Kinabalu, and *E. asonluca* from a *Tupaia* in Sarawak, are placed in the subgenus *Walchiella* Fuller.

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MALAYSIAN PARASITES VI

INDO-MALAYSIAN CHIGGERS OF THE SUBGENUS *SCHÖNGASTIELLA* (ACARINA TROMBICULIDAE)*

By

ROBERT TRAUB AND THOMAS M. EVANS.

During the war years intensive studies on scrub typhus were undertaken by the United States of America Typhus Commission in Assam and Burma. Postwar investigations on this mite-borne disease have been carried out in Malaya by the Colonial Office Research Unit and the U.S. Army Medical Research Unit, both headquartered at the Institute for Medical Research, Kuala Lumpur. As a result of these projects, quantities of trombiculid mites or chiggers have become available for study, including new and little-known species.

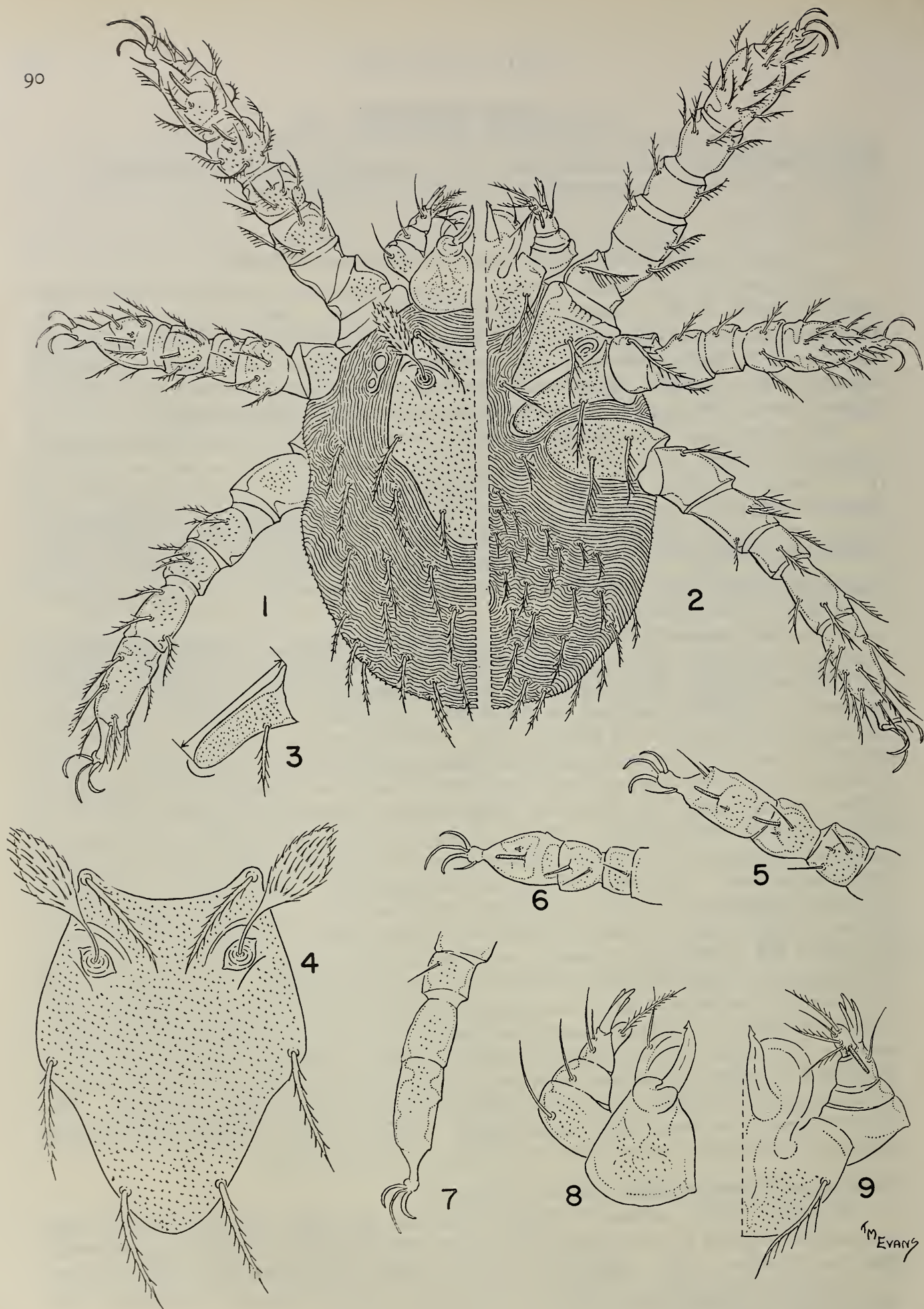
The present paper includes descriptions of the larvae of seven new species of the subgenus *Schöngastiella* (Hirst, 1915) of the genus *Gahrliepia* Oudemans, 1912, as well as records of *G. (S.) punctata* (Radford, 1946) and *G. (S.) ligula* (Radford, 1946). This group of mites is of potential medical significance, although its role has never been evaluated. The subgenus was regarded as wholly Indo-Malayan, but it has recently been reported in Africa (Andrè, 1951). The fact that new species are currently being described by other workers, whereas other species are yet poorly known and inadequately collected, makes it impossible to prepare a revision of this subgenus at the present time.

One of the Assam-Burma new species is described in detail. The other new forms are compared with the first, and only major differences are noted in order to save space. All these are illustrated in full. For purposes of ready comparison, a table is included which lists pertinent and significant data and measurements. In addition to the valuable measurements introduced by Womersley and Heaslip (1943), and which are now standard, new metric data and proportions, as well as terms and abbreviations, are included in the present paper. Among these are: (a) the pseudo-posterolateral setae (PPL): the pair of abdominal setae encompassed by the enlarged scutum, and which at first glance appear to be the posterolaterals; (b) PPW: the width in microns between PPL; (c) PP: the distance in microns between PPL and the posterior margin of the scutum; (d) A-PP: the distance between AL and PPL; and (e) DS: the length of typical dorsal setae. The ratio of PW to the scutal depth SD ($=ASB+PSB$), is a useful one, and serves to statistically equalize the apparent difference between the actual measurements of disproportionately large or small specimens of the same species. Important in this regard is the ratio of PW to the length of coxa II (see Traub and Audy, 1953, this *Study* p. 74). This ratio appears to be quite constant regardless of the size of the individual. The length of coxa II is measured as illustrated in fig. 3, i.e., from the base of the coxa (not the more contiguous plate, which is difficult to see in long-mounted specimens) to the tip of the apical spur on the anterior margin. The setation of the palpal femur is expressed by means of a formula after Audy (1952) e.g. N/N/BNB, in which the first letter refers to the seta on the palpal femur, the second to that of the genu, and the next three to the dorsal, lateral, ventral setae on the tibia, respectively. The letter N signifies the seta is nude, and B barbed. Where a bristle is mainly nude but lightly frayed or ciliated in one or two places the designation would be N(b).

***Gahrliepia (Schöngastiella) liota* n. sp. (figs. 1-9).**

Diagnosis of Larvae.—Near *G. (S.) ligula* (Radford, 1946) (figs. 61-68) in that the scutum is constricted beyond PL, the portion of the plate posterior to these bristles being somewhat narrowed (Radford, 1946). Separable in that the hind coxae possess two bristles, not one;

* Investigations supported by the Commission on Immunization of the U.S. Armed Forces Epidemiological Board and by the British Colonial Office Research Unit.



Gahrlepiea (Schöngastiella) liota n. sp.

Dorsum and Venter of Larva	1, 2
Coxa II showing measurement for PW/Coxa-II ratio	3
Scutum	4
Legs I, II, III	5, 6, 7
Mouthparts, Dorsal	8
Ventral	9

the posterior portion of the scutum is not nearly as narrow or ligulate; also distinct in that the scutum is smaller, i.e., AW 28-30 μ instead of with a mean of 39 μ ; PW about 45, not 52; with A-PP 56, not 71, but nevertheless A-P is about 36 while in *G. (S) ligula* the mean is 39.

Description of Larva.—*Body*: Subovate, somewhat constricted at anterior third, engorged specimen about 325 μ (including mouth-parts) long by 214 μ broad; ovate if not fully engorged. Eyes double, indistinct in specimens extant; apparently total dimensions about 13 $\times$ 5 μ . *Gnathosome*: chelicers about four or five times as long as broad at base; with a single subapical notch. Palpal coxae and femora punctate. Palpal setae as follows: femoral seta long, nude; genual seta similar, as are the three tibial setae. Thus the palpal setae formula is N/N/NNN. Palpal tarsus with a basal striated rod and about 5 bristles, some subapical, 4 of these heavily plumose, 1 apparently nude. Palpal claw trifurcate, of which only two prongs are readily discernible. Galeal seta simple. Maxillary seta plumose. *Scutum*: subpentagonal, but with angles rounded; with anterior margin slightly concave; broadest at insertion of posterolateral bristles (PL), then narrowing noticeably; margins slightly sinuate between anterolateral bristles (AL) and posterolateral bristles (PL), and more sinuate between PL and what are here designated as pseudo-posterolateral bristles (PPL) caudal margin broadly U-shaped posterior to PPL and extending beyond these bristles for a distance of about 1/8-1/10 length of plate. Dimensions of scutum in holotype: 76 $\times$ 50 μ . Lightly punctate, lacking striations of body. Cristae fairly well developed. Pseudostigmatic organs (sensillae) somewhat fusiform but with petiolate base; about 40 μ (total length, including petiole) by 9 μ ; barbules rather appressed; inserted at a level more than one-third length between AL and PL. Scutum setae well developed, heavily plumose; pseudo-posterolateral bristles (PPL) close together as compared with AL and PL. *Body Setae*: Dorsal setae similar to scutal setae; about 30 in number in rows 2,4,6,6,6,

STANDARD MEASUREMENTS IN MICRONS, *G. liota* n. sp.

U.S.A.T.C. Slide No.	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	PPL	DS	PW Coxa II	PW SD
3,561- 1	30	46	19	29	16	60	35	58	18	27	28	22	24	46/43 =1.07	46/76 =0.6
3,579- 2	30	49	21	31	16	60	36	56	20	27	28	23	24	49/45 =1.1	49/76 =0.6
1,482-24	28	45	22	28	16	58	35	54	20	26	27	24	25	45/42 =1.07	45/74 =0.6
2,044- 5	28	43	21	27	15	58	35	54	20	26	28	22	25	43/42 =1.0	43/74 =0.6
3,662- 1	31	47	21	27	16	62	36	58	19	27	27	23	24	47/44 =1.08	47/78 =0.6

the rest irregular. With a single pair of sternal setae between bases of coxae I and another smaller pair between coxae III. Ventral setae thin, short, plumose, about 40 in number, most about 13 microns in length. *Legs*: Coxae and legs punctate. Coxae I and II unisetose, the seta caudomarginal on II, nearly so on I; coxae III with two submedial setae. Sensory setae as follows: Leg I with 2 genualae, 1 microgenuala, 2 tibialae, 1 microtibiala, 1 spur, 1 microtarsala proximal to tarsala, 1 subterminala, 1 parasubterminala and 1 pretarsala. Leg II with 1 genuala, 2 tibialae, 1 tarsala spur, 1 adjacent microtarsala and one pretarsala. Leg III with 1 genuala. Tarsal claws triunguiculate, the middle claw slightly longer than other.

Type Material.—Collected in Assam, India, from true shrews, by members of the United States of America Typhus Commission in 1945. Holotype (U.S. National Museum 2066; U.S.A.T.C. 3561-1) ex *Suncus caeruleus fulvocinereus* Anderson, 22 miles north of Ledo on the Stilwell Road, 29. viii. 1945. A paratype with same data but 28. viii. A paratype ex *Suncus*, loc. cit. but taken at the 4.6 mile mark, 7. ix. A third paratype ex *Anourosorex squamipes assamensis* Anderson, a short-tailed shrew, but at the 15 mile mark, 27. vii. A fourth paratype ex *Crocidura* sp. at the 21 mile mark, 29. vii. Holotype and two paratypes deposited in the U.S. National Museum. Two paratypes in collection of senior author.

Gahrlepiea (Schöngastiella) erula n. sp. (Figs. 10-17).

Diagnosis of Larva.—Near *G. (S) punctata* (Radford, 1946) (figs. 69-76) in that the scutum is very broad and long, the scutal depth being over 105 and with PW over 60 μ . Readily separable in that the third coxae are unisetose instead of bearing 2 setae; the lateral margins of the scutum are evenly and gently convex, not angulate at level of PW and then rapidly converging; with PPW over 64 μ , not merely in the vicinity of 41 μ .

Description of Larva.—*Body*: subspherical in unengorged specimens, approximately 240 μ long by 180 broad; engorged specimens ovate, broadest behind coxae III, about 505 $\times$ 370 μ . Anterior eye 13 $\times$ 9 μ , posterior eye about 9 $\times$ 4 μ . *Gnathosome*: as in *liota* n. sp. *Scutum*: very large, about 130 $\times$ 80 μ ; elongate oval but anterior margin almost straight, very shallowly concave; lateral margins slightly convex; posterior margin evenly and deeply rounded; extending beyond PPL for a distance nearly one-third length of scutum. Sensillae about 36 $\times$ 15 μ , inserted at a level nearly midway between AL and PL. Scutal setae nearly contiguous with lateral margins of plate; PPL slightly further apart than are PL. *Body Setae*:



Gahrlepiea (Schöngastiella) erula n. sp.

Scutum	Dorsum and Venter of Larva	10, 11
Legs I, II, III	12	Mouthparts, Dorsal
	13, 14, 15	Ventral
		16
		17

STANDARD MEASUREMENTS IN MICRONS, *G. erula* n. sp.

Slide	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	PW Coxa II	PW SD
Holotype ...	40	75	75	45	22	103	40	90	35	31	36	26	75/57 =1.31	75/125 =0.6
Paratypes (6)														
Mean ...	38	70	72	42	19	106	39	89	36	30	35	28	1.3	0.6
Range (+ or -) ...	3	5	8	3	3.3	5	3	2	6	1	2	2.3	—	—

Dorsal setae similar to scutal setae in morphology but slightly smaller; about 28 or 30 in number (deleting PPL), arranged in rows of 2.4.8. or 2.6.6., the rest irregular. At times one or two of the four dorsal setae appear to be contiguous with scutal margin. Ventral setae thin, sparsely plumose, definitely shorter than dorsal setae, the anteriormost about 12 μ in length, the postanal (referred to by Audy, 1952, as caudal setae) about 22. All coxae with one seta.

Type Material.—Collected at Shingbwiang or else 10 miles north of Myitkyina, North Burma, by members of U.S. Typhus Commission ex *Rattus fulvescens fulvescens* (Gray), *Rattus rattus sladeni* (Anderson) and *Rattus flavipectus yunnanensis* (Anderson) in 1945. Holotype (U.S.N.M. 2067; U.S.A.T.C. 906-17) ex *Rattus rattus sladeni*, Shingbwiang, 6. iv. 1945. Sixteen paratypes from these hosts and localities deposited in the collections of the U.S. National Museum, the Colonial Office Research Unit at Kuala Lumpur, in the collections of the senior author and in various institutions.

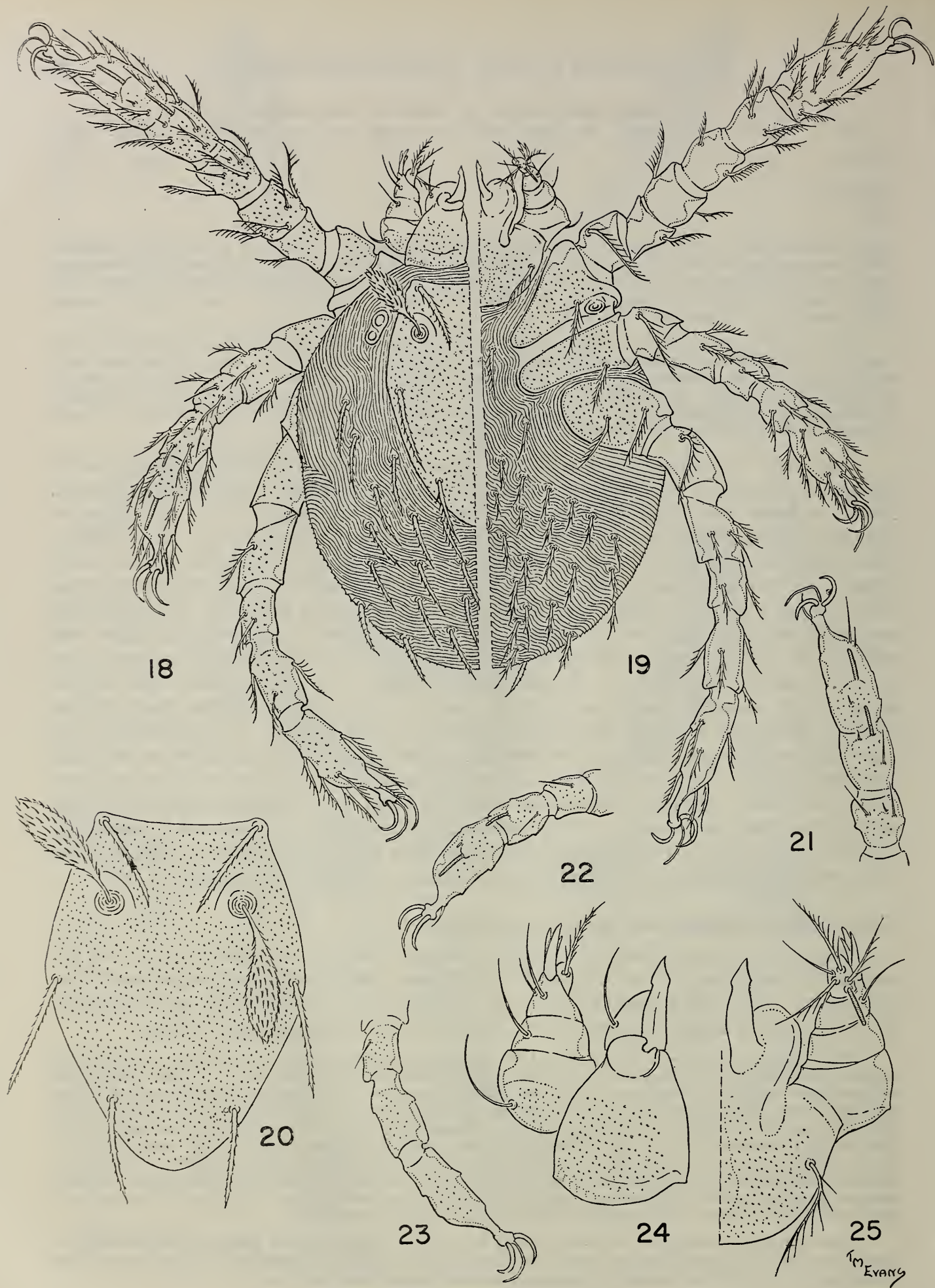
Comment.—*G. (Schöngastiella) erula* n. sp. seems to be a characteristic but relatively scarce parasite of *Rattus* in or near dense or primary forest in North Burma during the drier months. Most specimens were from *Rattus fulvescens* collected at the height of the dry season at Shingbwiang in virgin forest or in areas that had been so one year previous. At the time of collection these latter areas were near camps of U.S. Army troops building the Stilwell Road. These sites were still densely covered with trees. In this location, some were from *Rattus rattus sladeni*, a rat occurring in the fringe of scrub terrain along the road. The Myitkyina specimens were also from forested regions. Of the 25 specimens examined, only three were taken in the non-dry months, and these were collected just before or after the monsoon rains (in early June and late October). Despite intensive search, none of these mites were taken in areas of truly secondary growth as near Ledo, Assam or near the Sumprabum Road, 6 miles north of Myitkyina, nor were any collected during the rainy season. Four specimens, from four different individual hosts, are remarkable in possessing only 11-21 dorsal setae instead of the normal 28-30. No other significant differences could be detected between these specimens and typical *erula*. One of these forms was from a host (No. 819) which also carried specimens of *erula* designated as paratypes. This variation in the number of dorsal setae is surprising, but with insufficient knowledge of the taxonomy of these mites, it is felt best to consider these four specimens as aberrant forms rather than as distinct specimens of subspecies.

***Gahrliepia (Schöngastiella) helata* n. sp. (figs. 18-25).**

Diagnosis of Larva.—Near *G. liota* n. sp. in that coxae III are bisetose and in that the scutum is of small size. Separable mainly by the shape, measurements and proportions of the scutum, i.e.—PPW with a mean of 29 μ , not 21: A-PP 67 not 56: scutum evenly curved posterior to PW, instead of being constricted at that point and then becoming slightly sinuate.

Description of Larva.—*Body*: subovate; in engorged specimens about 200 $\times$ 128 μ . Anterior eye approximately 6.4 $\times$ 3.2 μ ; posterior eye about 7 $\times$ 5 μ . *Gnathosome*: as in *liota*. *Scutum*: broad and elongate as in *erula* n. sp. but shorter than that species, about 80 $\times$ 60 μ at maxima, anterior margin almost straight; lateral margins evenly but slightly convex; posterior margin broadly rounded; extending beyond PPL for a distance less than 1/6 length of scutum. Sensillae about 34 $\times$ 11 μ , inserted at level slightly less than halfway between AL and PL. Scutal setae near margins of dorsal plate but not contiguous with them. PPL closer together than are PL setae, but their breadth (PPW) more than half PW. *Body Setae*: Dorsal setae similar to scutal setae; about 30-32 in number in rows of 2.4.8.8.6. the rest irregular. Ventral setae about 40 in number; thin, sparsely plumed, short, the anteriormost about 10 μ in length, the postanal about 21. As in *liota* n. sp. regarding bisetose coxa III and sensory setae.

Type Material.—Holotype (U.S.N.M. 2068; U.S.A.T.C. 834-9) and six paratypes ex *Crocidura*, a small shrew, North Burma, Shingbwiang, 10. i. 1945 (U.S.A. Typhus Commission). Holotype and two paratypes in U.S. National Museum; remainder in collection of senior author.



Gahrlepiea (Schöngastiella) helata n. sp.

Scutum	Dorsum and Venter of Larva	18, 19	
Legs I, II, III	20	Mouthparts, Dorsal	24
	21, 22, 23	Ventral	25

STANDARD MEASUREMENTS IN MICRONS, *G. helata* n. sp.

Slide	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	$\frac{PW}{Coxa II}$	$\frac{PW}{SD}$
Holotype ...	34	52	29	35	17	64	36	64	17	28	27	26	$\frac{52}{46}$ =1.13	$\frac{52}{81}$ =0.64
Paratypes (6)														
Mean ...	32	54	29	34	17	66	36	67	18	28	29	25	1.16	0.66
Range ...	2	4	2	2	2	3	2	3	2	2	3	4	—	0

Comments.—One specimen from Assam (Ledo vicinity, 22-mile mark on Stilwell Road), ex *Suncus*, agrees fully with the above description. It was collected from the type host and locality of *G. liota* n. sp. above, a species which is close to *G. helata* n. sp. as noted in the diagnosis. However, such a geographic distribution is not unique in this genus. According to our current concepts, the differences in the proportions of the scutum indicate we are dealing with full species, but the possibility of extreme variations within one species must be borne in mind.

Gahrlepiea (Schöngastiella) birella n. sp. (figs. 26-34).

Diagnosis of Larva.—Readily separable from all species of *Schöngastiella* known to date by the conspicuous straight row of greatly enlarged dorsal bristles which extend on each side in an oblique sublateral line from level of anterior margin of scutum to lateroposterior margin of body, and by the well-developed anal plate (which is even more specialised in a new species described below). Agrees with *G. erula* n. sp. in coxa III being unisetose and in possessing a scutum which is broadly ovate posteriorly and with PW about 66-70 μ . Further separable from *erula* by PSB being below 86, not above 100.

Description of Larva.—*Body*: ovate, about 325 μ $\times$ 250 μ when engorged. Eye apparently single, but indistinct in specimens extant. *Gnathosome*: of type characteristic of subgenus, but palpal coxae and femora scarcely punctate. *Scutum*: definitely punctate; about three-fourths as broad as long (about 75 $\times$ 103 μ in holotype); broad throughout, but slightly angled at level of PL; between AL and PL lateral margins somewhat oblique, diverging towards rear; these margins straight between AL and PPL but becoming convex at PPL so that scutum is somewhat constricted above these bristles; caudal margin evenly rounded. *Sensillae* absent in known specimens. *Body Setae*: Bases of dorsal and ventral setae

STANDARD MEASUREMENTS IN MICRONS, *G. birella* n. sp.

Slide	AW	PW	PPW	SD	ASB	PSB	A-P	A-PP	PP	AL	PL	DS*	$\frac{PW}{Coxa II}$	$\frac{PW}{SD}$
25369 ...	38	70	61	38	19	84	27	61	43	21	21	$\frac{19}{44-50}$	$\frac{70}{56}$ =1.25	$\frac{70}{103}$ =0.68
25263 ...	38	66	60	36	19	82	29	61	40	19	22	$\frac{21}{32-50}$	$\frac{66}{54}$ =1.2	$\frac{66}{101}$ =0.65

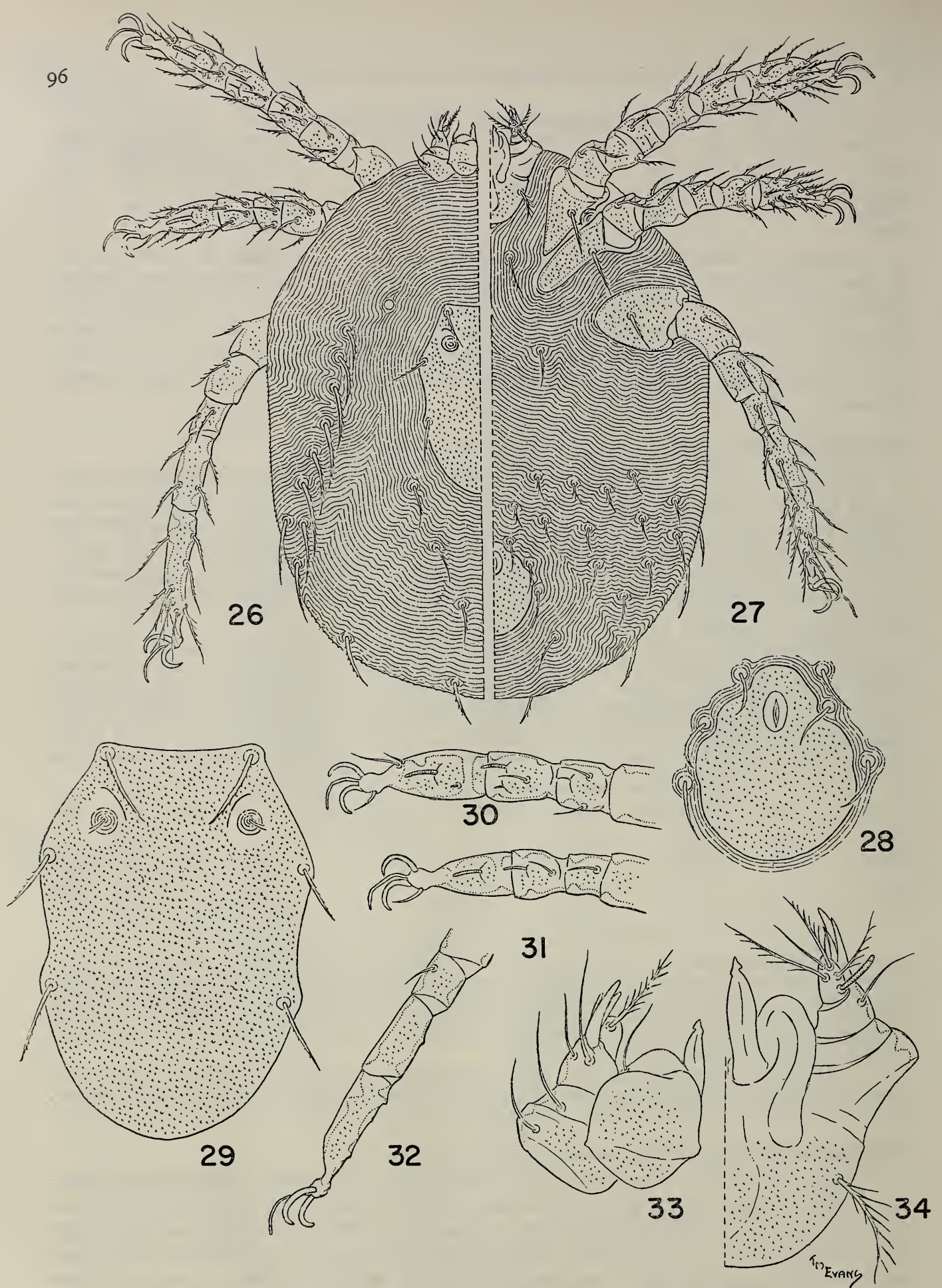
* Dorsal setae in prominent row become progressively larger proceeding caudad.

somewhat enlarged, prominent. Dorsal setae of two types: a thin, sparsely plumed form, only about 20 μ in length, about ten in number, all posterior to scutum and subdorsal in position; a second type, much stouter, ranging 32-50 μ in length, the longer ones more posterior in position, about eight on each side, forming a well-developed sublateral vertical row. Ventral setae about 36 in number, about 12 μ in length. Anal opening surrounded by an ovate bivalvular sclerotization, the structure lying on a distinct slightly crenulate, punctate plate about 30 $\times$ 45 μ (fig. 28).

Type Material.—Holotype (U.S.N.M. 2070, Colonial Office Research Unit 25369) ex *Rattus bowersi* (Anderson), Malaya, Selangor, Ulu Langat, 4. iii. 1952. (*J. R. Audy*); deposited in U.S. National Museum. A paratype (C.O.R.U. 25263) ex *Rattus*, Malaya, Selangor, Kepong, *ibid*; in collection of senior author.

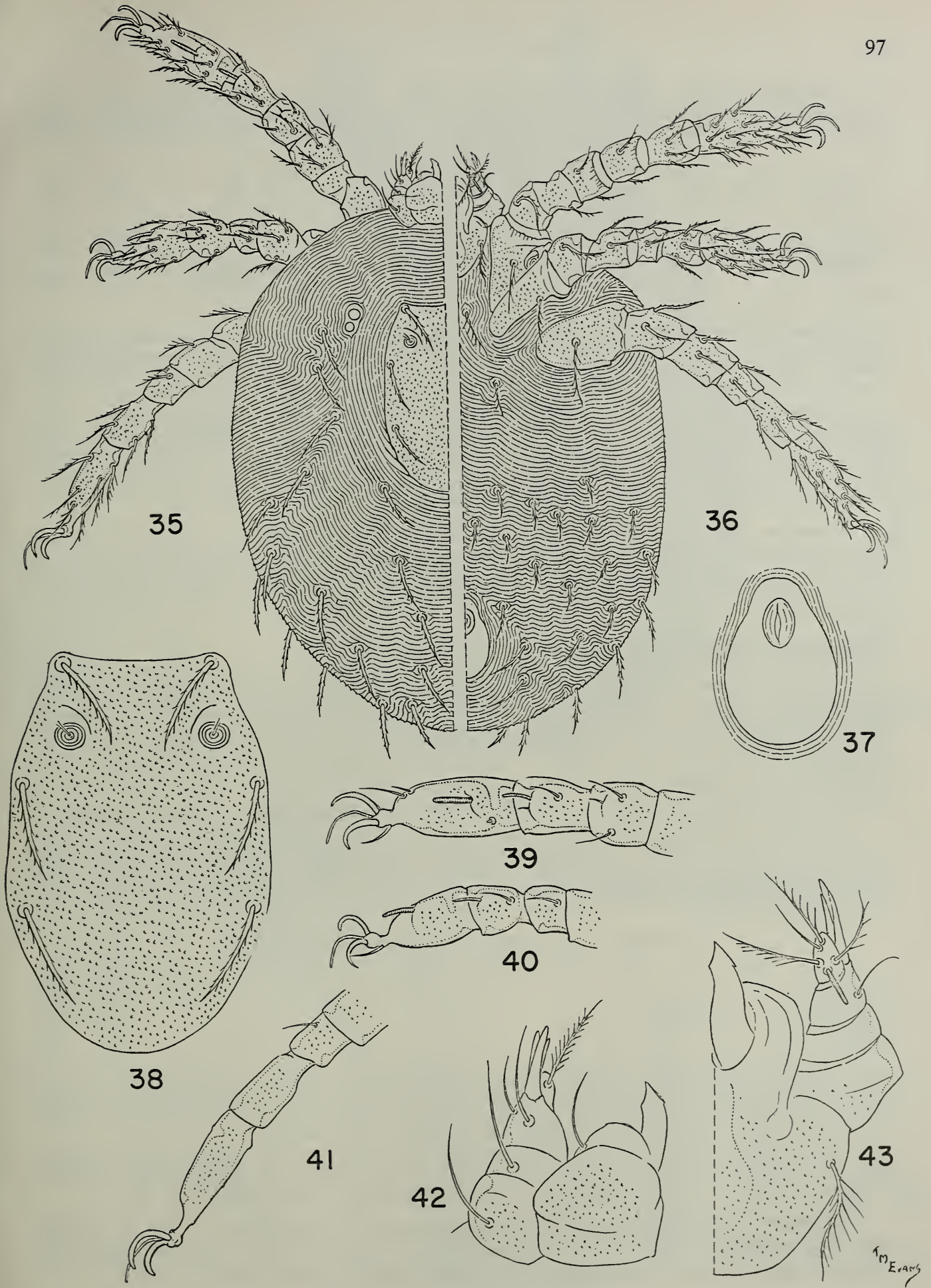
Gahrlepiea (Schöngastiella) arona n. sp. (figs. 35-43, p. 97).

Diagnosis of Larva.—Agrees with *G. (S.) birella* n. sp. in possessing a sclerotized anal plate (the only two species in the genus so characterized). Readily separated from *birella* by the absence of a row of enlarged dorsal bristles on each side of the scutum; by possessing longer AL (29 μ versus 19-21) by the greater degree of sclerotization of the anal valvular sclerite and anal plate; the anal plate $\frac{3}{4}$ as broad as long instead of virtually as broad as long; anal plate smooth, not punctate; and by the scutum being evenly rounded laterally.



Gahrlepieia (Schöngastiella) birella n. sp.

Dorsum and Venter of Larva	26, 27
Anal plate	28
Scutum	29
Legs I, II, III	30, 31, 32
Mouthparts, Dorsal	33
Ventral	34



Gahrlepiea (Schöngastiella) arona n. sp.

Dorsum and Venter of Larva	35, 36
Anal plate	37
Scutum	38
Legs I, II, III	39, 40, 41
Mouthparts, Dorsal	42
Ventral	43

1 m Erans

Description of Larva.—Engorged specimen $364 \times 298\mu$. *Gnathosome*: as in *G. birella* n. sp., scutum also similar but lateral margins more evenly rounded, not as angulate anteriorly and lacking a median constriction; more finely punctate. *Sensillae* absent in specimens extant. *Body Setae*: Bases of dorsal

STANDARD MEASUREMENTS IN MICRONS, *G. arona* n. sp.

Slide	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$
Holotype ...	37	64	62	37	21	85	34	69	37	29	26	26	$\frac{62}{52}$ =1.15	$\frac{62}{106}$ =0.59
Paratypes (15)														
Mean ...	35	60	57	35	22	82	34	66	35	30	26	27	$\frac{59}{50}$ =1.18	$\frac{59}{104}$ =0.57
Range (+ or -) ...	2	4	5	3	2	4	2	4	2	2	2	3	—	—

and ventral setae somewhat enlarged, prominent. Dorsal setae relatively long and thin, about 28 or 30 in number; 3 or 4 of these singly in an irregular line midway between lateral margins of scutum and sides of body. Ventral setae about 36 in number, about 15μ in length. Anal plate (fig. 37) ovate, about $50 \times 36\mu$ nearly as well sclerotized as scutum; the valvular sclerite around anal aperture well demarcated.

Type Material.—Holotype (U.S.N.M. 2069; C.O.R.U. 29214). and two paratypes ex *Rattus mülleri* (Jentink), Malaya, Selangor, Ulu Langat, 5.viii.1952 (*J. R. Audy*), in U.S. National Museum. Two paratypes, with same data, in British Museum of Natural History, and 5 *ibid*, in collection of Colonial Office Medical Research Unit, Kuala Lumpur. Two paratypes in collection of senior author, *ibid*, but ex *Rattus whiteheadi* (Thomas), Selangor, Kepong. Twelve additional paratypes with same data as holotype, distributed among various acarological collections.

Comment.—The nymph of this species has been bred by Messrs. Nadchatram and Lee Fatt-Hing of the Colonial Office Unit. It is a typical Gahrlepiine and the anal plate appears to have no homologue in the nymphs. The nymph is to be described later (Womersley and Audy, in MS).

Gahrlepieia (Schöngastiella) kalrata n. sp. (figs. 44-52).

Diagnosis of Larva.—Near *G. (S.) ceylonica* Womersley, 1952, in the scutum being markedly and narrowly ligulate posterior to PL and in possessing multisetose coxae III. Separable from that species in that the scutum is proportionately much larger, AW ranges from $47-56\mu$, not 31 and PW about $47-58\mu$, not 28. Proportionately large size of scutum reflected in ratio of PW/Coxa-II, which is over 0.84; in *ceylonica* it is less than 0.72. With over 80 ventral setae instead of approximately 60. Coxae III typically bearing 5 setae each and only rarely 4.

Description of Larva.—Approximately 680 by 480μ in engorged specimen. Eye apparently single, at level between AL and SB. *Gnathosome*: with femoral setae slightly barbed or plumed (other palpal setae nude as in *liota* n. sp. and related forms). *Scutum*: markedly narrowed beyond PL so that scutum is flask-shaped; apex rapidly becoming subacuminate beyond PPL. Pseudo-posterolateral bristles (PPL) often inserted at different levels, so that bases are in an oblique line, not horizontal. *Body Setae*: Dorsal

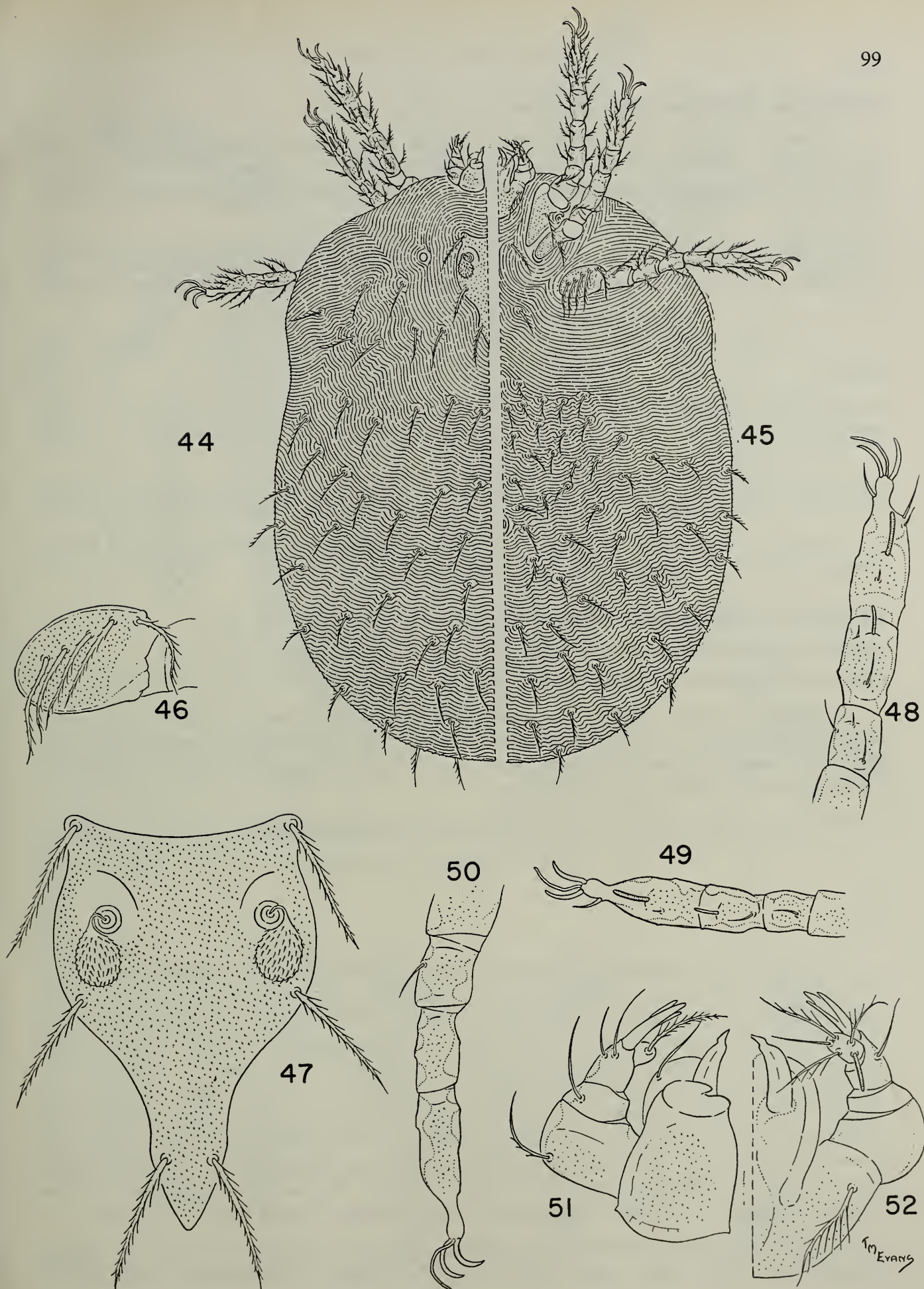
STANDARD MEASUREMENTS IN MICRONS, *G. kalrata* n. sp.

Slide	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$
Holotype ...	56	58	19	47	28	98	47	101	25	29	36	31	$\frac{58}{60}$ =0.96	$\frac{58}{126}$ =0.45
Paratypes (8)														
Mean ...	50	53	17	43	26	89	46	94	25	29	36	34	0.98	0.47
Range (+ or -) ...	4	6	3	4	3	12	5	11	8	3	2	2	0.08	0.02

setae as scutal setae but slightly smaller; about 70 in number, arranged in rows beginning 4.8.(10) 10 (12) and therefore quite variable. Ventral setae about 85 in number, anteriormost about 21μ in length, posterior ones about 28. Coxae III usually with 5 setae; at times with 5 on 1 and 4 on other, or 4-4; the most dorsal of these inserted at upper lateral angle of coxa, at times inapparent.

Type Material.—Holotype (U.S.N.M. 2071) ex *Rattus rattoides* ssp. (*turkestanicus*?), Kashmir, Sonmarg, viii.1949 (S.L. Kalra). Six paratypes, *ibid*, or ex 'Mouse', Kashmir, Baltal, *ibid*, deposited in collections of the U.S. National Museum, the British Museum, and of the senior author.

Comment.—The specific name was suggested by that of the collector, Lt-Col. S. L. Kalra, who has contributed much to our knowledge of scrub typhus. We are indebted to Dr. Audy for allowing us to study and describe this material, which was sent to him by Kalra.



Gahrlepieia (Schöngastiella) kalrata n. sp.

Dorsum and Venter of Larva	44, 45
Scutum	46
Legs I, II, III	47
	48, 49, 50
Mouthparts, Dorsal	51
Ventral	52

Gahrliepia (Schöngastiella) gammonsi n. sp. (figs. 53-60).

Diagnosis.—Near *G. (S.) helata* n. sp. in that the scutum is nonligulate and the third coxae bear 2 setae. Readily separable by virtue of the long narrower scutum ($PW:SD=51:103=0.50$), with PSB 82μ , not approximately 66; with dorsal setal rows commencing 2-6-6-6-, not 2-4-8-8.

Description of Larva.—*Body*: About 358μ in length, 245 in breadth in engorged specimen. *Gnathosome*: as in *liota* n. sp. *Scutum*: elongate oval, more narrowed behind PL than anteriorly; setae submarginal. A-PP about twice A-P. PSB nearly four times ASB. *Body Setae*: Dorsal setae essentially

STANDARD MEASUREMENTS IN MICRONS, *G. gammonsi* n. sp.

	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$
Holotype ...	33	51	22	35	21	82	39	77	23	25	29	25	$\frac{51}{46}=1.11$	$\frac{51}{103}=0.5$

as scutal setae but slightly smaller in size; about 28 in number, anterior rows arranged 2.6.6.6. Ventral setae about 52 in number of which approximately 20 are post-anals; anteriormost about 14μ in length, postanals 17-23 μ .

Type Material.—Holotype (only specimen extant) ex *Anourosorex squamipes assamensis* Anderson, a short-tailed shrew; India, Assam, 21 miles north of Ledo, 25.x.1945 (R. Traub and D. P. Millsbaugh for U.S.A. Typhus Commission). Deposited in U.S. National Museum (U.S.N.M. 2072).

Comment.—The species is named for John G. Gammons of the Army Medical Service Graduate School, Washington, who has helped us on many occasions.

Gahrliepia (Schöngastiella) ligula (Radford, 1946) (figs. 61-68, p. 102).

Schöngastiella ligula Radford, 1946, *Proc. zool. Soc. London*, 116, 256, figs. 17, 18.

Gahrliepia (Schöngastiella) ligula, Wom., 1952, *Rec. S. Aust. Mus.*, 10, 296-297, Pl. 77, fig. B-F.

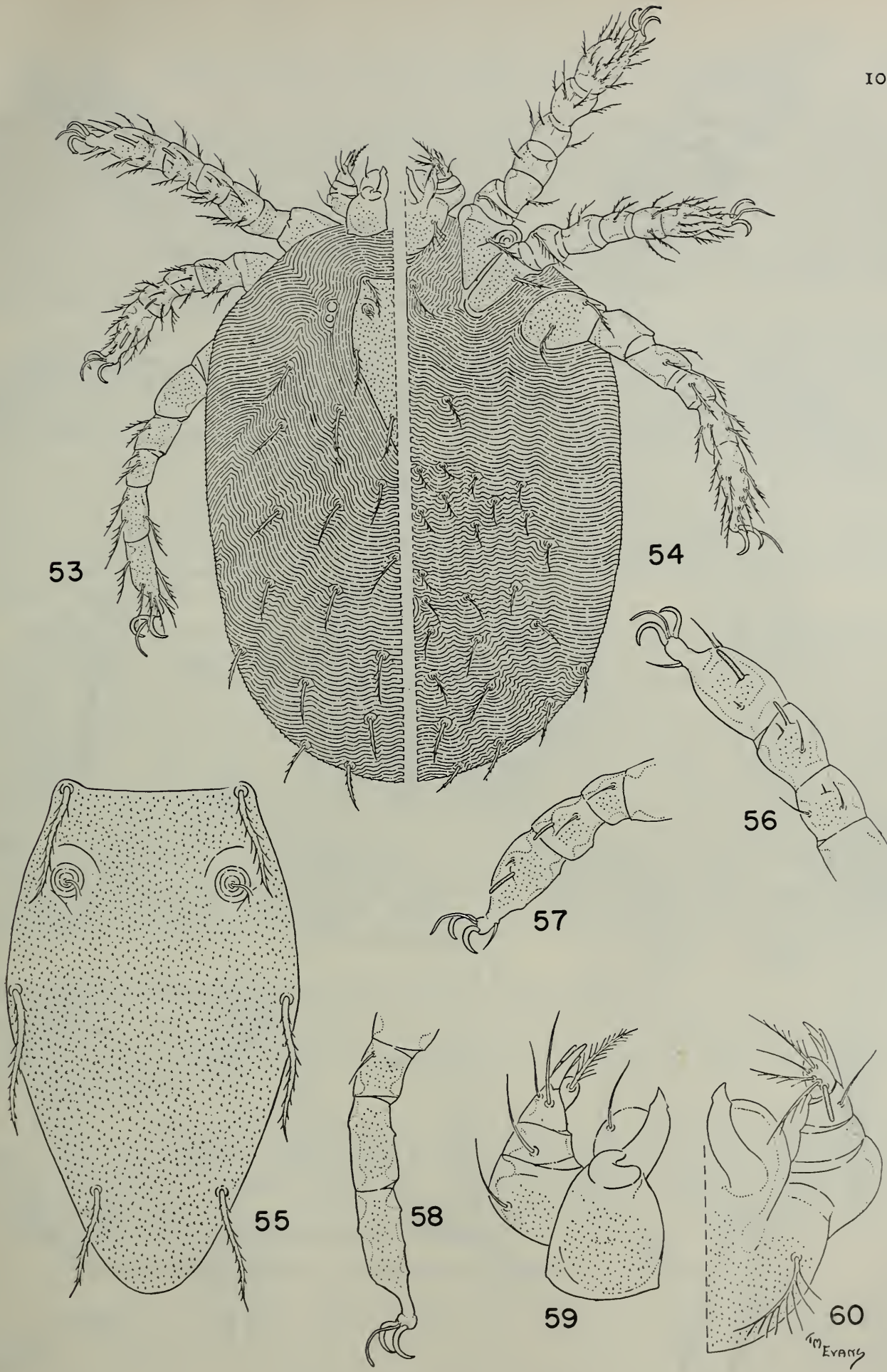
Diagnosis.—Scutum ligulate, the scutum narrowing immediately behind PL to form a tongue-like extension; the pseudo-posterolateral setae close together ($9-20\mu$) and inserted only about 12μ from the apex: all palpal setae about 38-44 in number, in rows of 2-4-8-8, or 2-6-8-2-8; ventral setae about 50 in number.

The Standard Measurements of 25 Assam and Burma specimens of *G. ligula* are as follows:

	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	$\frac{PW}{Cox II}$	$\frac{PW}{SD}$
Mean ...	39	52	14	34	22	58	39	71	9	35	38	35	$\frac{52}{59}=0.8$	$\frac{52}{80}=0.65$
Range (+ or -) ...	8	10	5	4	4	6	4	5	4	8	8	7	0.10	0.10

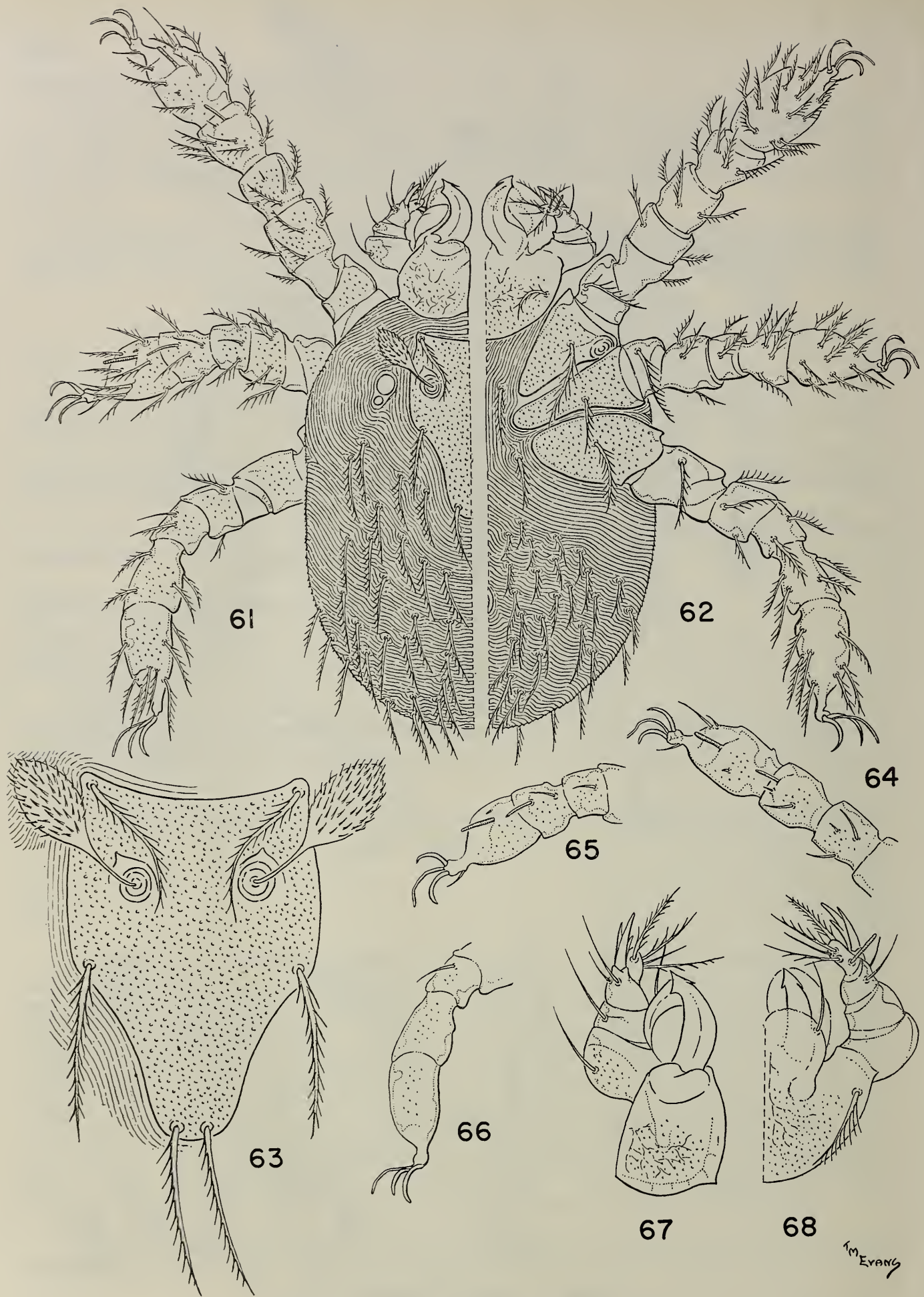
Comments.—Our collections demonstrate that *G. ligula* is even more variable morphologically than the wide range of measurements recorded by Womersley (1952) indicate. The great variations in setal pattern noted above, as well as of the standard data, frequently occur in a series from an individual host. This species is a prime example of how one can be misled by taxonomically studying inadequate series of trombiculids. If one were to study only the extremes of variation, two or three synonyms of *ligula* could very easily be created. Of particular interest in this regard is a group of specimens collected on the floor of a small man-made cave sheltering bats near Myitkyina and not included in the above measured series. These five specimens are peculiar in possessing about 80 ventral setae instead of 50, and the standard measurements are definitely greater, i.e., PW 62, PSB 68. The biological significance of these differences cannot be evaluated at the present time and hence no new name is proposed.

G. ligula was collected during all times of the year on 120 occasions by the U.S.A. Typhus Commission in the Ledo Assam area and in the vicinity of Myitkyina, North Burma.



Gahrlepiea (Schöngastiella) gammonsi n. sp.

Scutum	Dorsum and Venter of Larva	Mouthparts, Dorsal	53, 54
Legs I, II, III	55	Ventral	59
	56, 57, 58		60



Gahrlepiea (Schöngastiella) ligula (Radford, 1946)

Scutum	Dorsum and Venter of Larva	61, 62	
Legs I, II, III	63		67
	64, 65, 66	Mouthparts, Dorsal	68
		Ventral	

Approximately 90 per cent. of the time the hosts were *Rattus flavipectus yunnanensis* or *Rattus rattus sladeni*. The remainder of the hosts were *Mus bactrianus kakhyensis*, *Rattus manipulus*, *Tupaia belangeri versurae*, *Crocidura* (twice), and once each from *Herpestes*, *Suncus*, *Anourosorex*, *Bandicota*, and an unidentified bird. As the types of hosts indicate, the species was rarely taken near or in the primary jungle at Shingbuiyang. In North Burma in the dry season, frequently 40-80 per cent. of the chiggers taken on rats were of this species. In the rainy months in Assam the incidence was only in the vicinity of 10-30 per cent. It is possible that this difference is geographical rather than seasonal.

The distribution of this species around Imphal was noted by Audy (1947) as an "undescribed species of *Schöngastiella*" (Audy, personal communication). It was recorded by the British Scrub Typhus Research Laboratory as common on *R. rattus bullocki* and present on *Rattus* sp. indet., *R. manipulus*, *Callosciurus* sp., *Suncus* (probably *S. murinus*), and *Anourosorex squamipes* in the Manipur area, and as very common on *R. rattus khyensis* and *Bandicota bengalensis* in South Burma—it appeared to be commonest on rodents from villages and towns in both Manipur and South Burma (70-80 per cent of rats or bandicots infested), and appeared at least in Manipur to be the counterpart of the characteristically urban species *Euschöngastia indica* (Audy *et al.*, 1953, and Audy, personal communication). These workers also found that the incidence of *G. ligula* was low during the height of the rainy season (July-August), with a peak in October-November at the end of the rains.

Womersley reports, from collections by Kalra, that this species is also abundant in Kashmir. The frequency of occurrence of this chigger on rats inhabiting scrub terrain suggests that its possible role in scrub typhus should be further studied. This mite is not known to bite man, but it may serve as an intramurine vector of *Rickettsia tsutsugamushi*. *G. ligula* has several times been found in samples selected from batches of chiggers from which *R. tsutsugamushi* was isolated. Kalra (1947) reported a successful isolation in an instance where the sample examined seemed to consist entirely of *ligula*. Although unlikely because of its distinctive colour, the presence of the established vector, *T. deliensis*, could not be absolutely excluded. Davis *et al.* (1947) reported the isolation of several strains of *R. tsutsugamushi* from pools of mites in which a very low percentage of the mites examined consisted of *ligula*. (These were reported as *Schöngastiella* species, but the Gahrlepiine slides and unpublished records of the India-Burma Field Party of the U.S.A. Typhus Commission, in the possession of the senior author make possible this complete determination).

Gahrlepieia (Schöngastiella) punctata (Radford, 1946) (figs. 69-76).

Schöngastiella punctata Radford, 1946, *Proc. zool. Soc. Lond.*, 116, 256, figs. 19, 20.

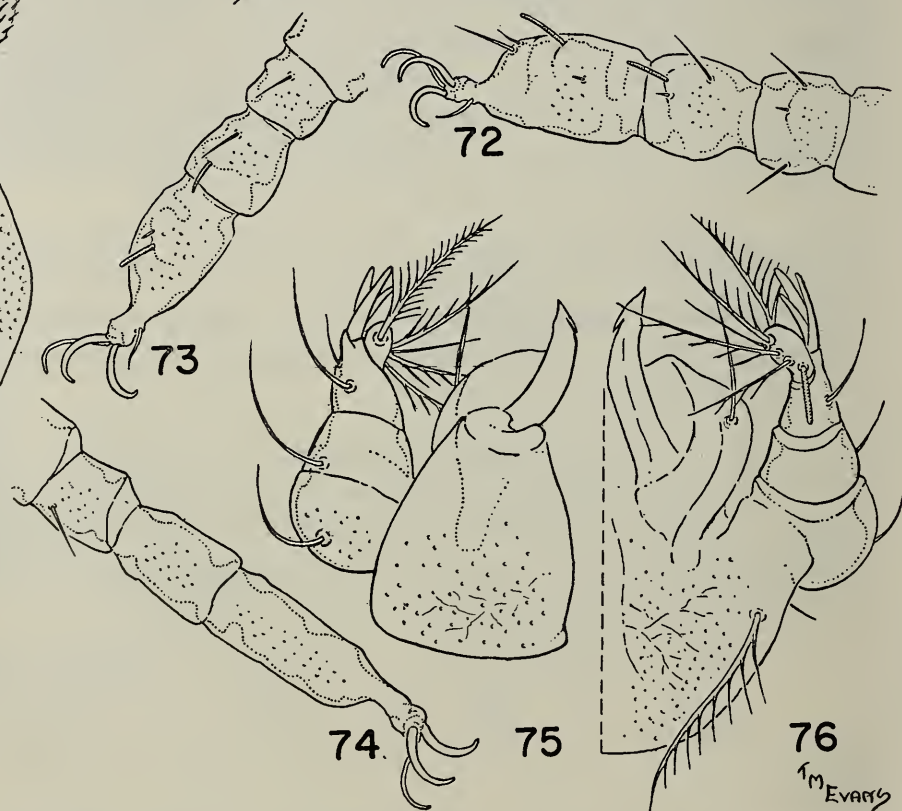
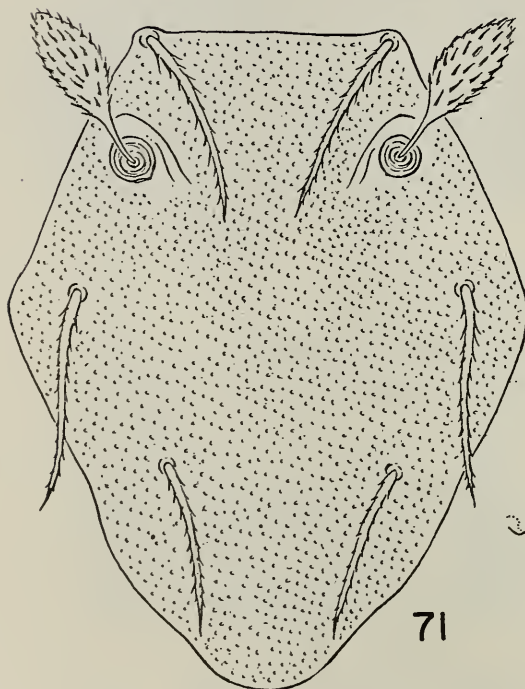
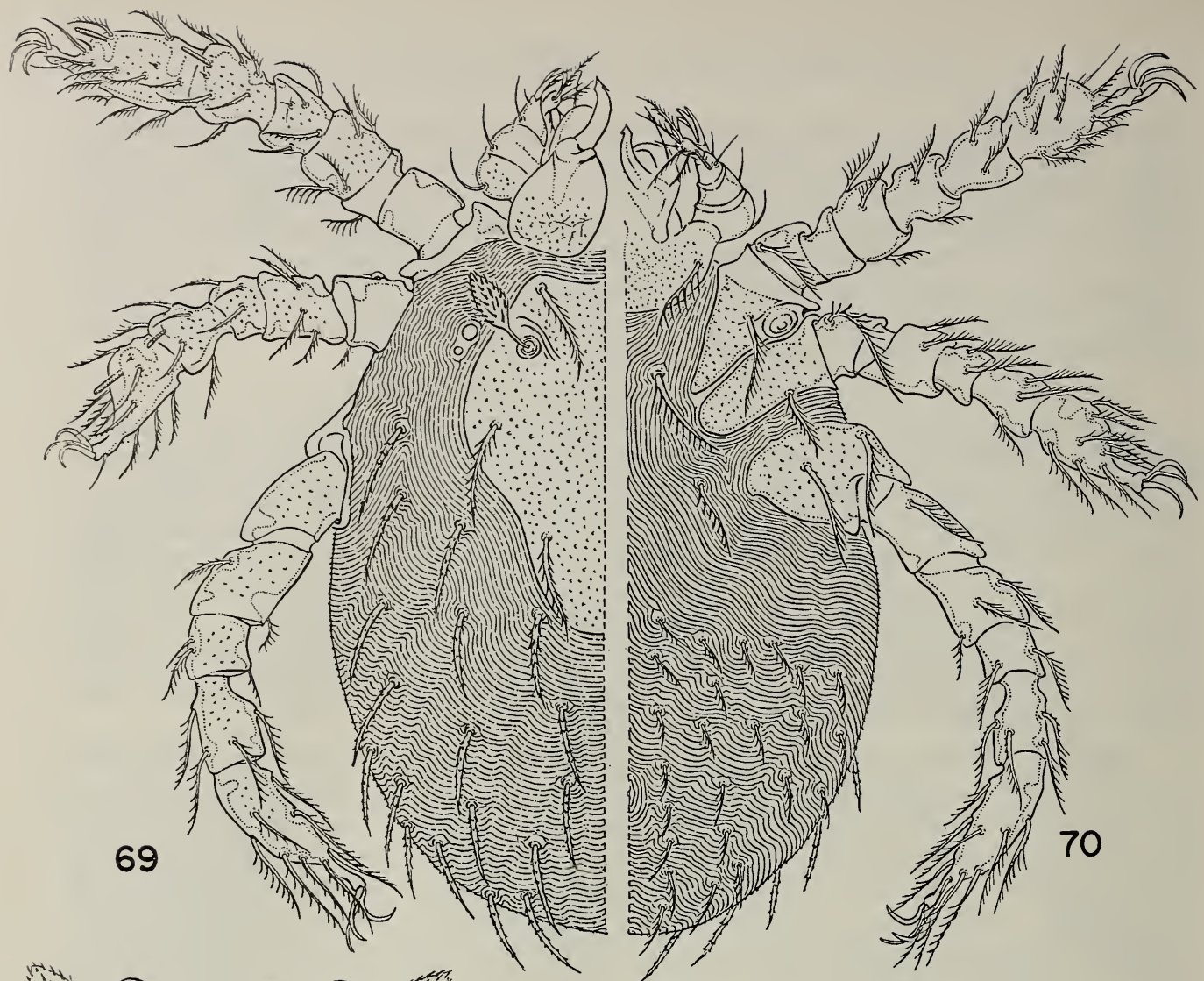
Gahrlepieia (*Schöngastiella*) *punctata*, Womersley 1952. *Rec. S. Aust. Mus.*, 10, 299-300, Plate 78, Fig. C.

Diagnosis.—With a large subpentagonal scutum which is characteristically angled at level of PL (fig. 71) but which is rarely rounded and then sinuate as in fig. 69. PW about 73, PPW about 42; Coxae III bisetose. Palpal setal formula N/N/NNN. Sensory setae of legs of usual type (as in *liota* n. sp.). With about 33 dorsal setae in irregular rows beginning 2.4.6.2.6. Ventral setae about 35 in number and 20 μ in length.

STANDARD MEASUREMENT OF 15 SPECIMENS OF *G. punctata* FROM ASSAM AND BURMA

	AW	PW	PPW	SB	ASB	BSB	A-P	AA-PP	PP	AL	PL	DS	PW Cox II 71/63 =1.11	PW SD 71/119 =0.6
Mean ...	42	71	41	46	21	98	46	83	36	38	41	33		
Range (+ or -)	3	6	5	4	3	8	5	6	7	3	3	3	1.1	0.05

MALAYA, No. 26, 1953



Gahrliepia (*Schöngastiella*) *punctata* (Radford, 1946)

Scutum	Dorsum and Venter of Larva	69, 70				
Legs I, II, III		71				
		72, 73, 74	Mouthparts, Dorsal			75
			Ventral			76

1m EVANS

Comments.—*G. punctata* is a characteristic parasite of shrews in Assam and North Burma. Fifty-four of 60 parasitized hosts examined by the U.S.A. Typhus Commission were shrews of the genera *Crocidura*, *Suncus*, and *Anourosorex*. The remainder were *Rattus rattus sladeni*, *Rattus flavipectus yannanensis* and *Mus bactrianus kakhyensis*. As a rule less than 10 per cent. of the chiggers on the shrews were of this species, but at times as high as 21 of 24 chiggers sampled per host were *G. punctata*. This chigger was not encountered by us in the truly dry season. The localities represented were in scrub vegetation in the Ledo, Assam, area and in the vicinity of Myitkyina, North Burma. Two specimens were collected from a shrew in secondary growth at Shingbuiyang, North Burma. *G. punctata* was originally described from a *Suncus* collected at Kanglatongbi near Imphal, by the British Scrub Typhus Research Laboratory. This unit recorded *punctata* from 49 shrews and 10 *Rattus r. bullocki*, mostly in April-July (51 hosts), but with 5 hosts in August, 2 in September and 1 in November. Two records were from near Kalewa on the Chindwin Burma, but this species was not recorded from South Burma (Rangoon-Prome-Toungoo area) (Audy, personal communication). Womersley records *G. punctata* from Ceylon.

The North Burma and Assam specimens referred by us to this species do not quite agree with Womersley's descriptions. He cites the palpal femoral seta as being lightly branched, while the palpal claw is "apparently bifurcate". In our series the palpal femoral seta is nude and the claw seems trifurcate. Nude setae in this group of trombiculid mites at times appear frayed, while the palpal claw prongs are often difficult to see clearly. The discrepancies are therefore considered inconsequential.

Gahrlepieia (Schöngastiella) hipposideros (Audy, 1952).

Schöngastiella hipposideros Audy, 1952, *Bull. Raffles. Mus.*, 24, 148-151, figs. 5, 6.

Diagnosis.—The author's diagnosis may be quoted : 'This species is very close to *S. punctata* Radford, from shrews and rodents in Manipur (India), Burma, and Ceylon, and differs in the narrower scutum (posterior setae close to the edge) and the unisetose coxa III, which is 2-setose in *punctata* (and 4-setose in the closely related *S. kumaonensis* Wom.), and the arrangement of body setae lateral to the scutum (2.4.4. in *hipposideros* and 2.2.4. in *punctata*). In *punctata* the scutum at the level of the PLs is some 7-10 μ wider than PW (see fig. 6).' Coxa II measures 41.5 μ giving a PW/Coxa-II ratio of 1.35 (personal communication).

Type Material.—A single holotype from a horseshoe bat, *Hipposideros* sp., from Bukit Lagong Forest Reserve, near Kuala Lumpur, 5.ix.1951.

Comment.—This specimen has not been studied by us. Its relationships cannot be properly assessed without more material, and it is included in the present paper to complete records of species of *Schöngastiella* so far described from Malaya.

Comment on the Subgenus Schöngastiella

As can be noted from the illustrations and descriptions above, the species of the subgenus *Schöngastiella* are remarkably uniform concerning the setation of the palpi and the sensory setae of the legs. The palpal setae are virtually always nude—only in *G. kalrata* n. sp. and *G. punctata* (Radford, 1946) is there an indication of barbs on these setae. Here the palpal femoral setae is at times frayed or slightly barbed. All the species discussed have the same sensory setae as that described for *G. liota* n. sp.

The postlarval stages are outside the scope of this paper but it may be recorded that nymphs of the following species have been bred and described : *ceylonica*, *ligula*, *punctata* and *arona* (in MS).

Comparative Measurements and Data of Seven Species of Indo-Malaysian Mites of the Subgenus *Schöngastiella*

Species	Scutum posteri- only lingulate	AW	PW	PPW	SB	ASB	PSB	A-P	A-PP	PP	AL	PL	DS	PW	Setae Coxae III	Anal Plate
<i>liota</i> (mean)	...	30	46	29	29	16	60	36	56	19	26.5	27.5	23	46/43 =1.07	0.6 0.03	0
(range)...	...	2	3	2	2	1	2	1	2	1	0.5	0.5	1	0.03		
<i>erula</i> ...	...	38	70	72	42	20	106	39	89	36	30	35	28	70/54 =1.3	0.6	0
	...	3	5	8	3	3	5	3	2	6	1	2	2	0.04		
<i>helata</i> ...	...	32	54	29	34	17	66	36	67	18	28	29	26	54/45 =1.16	0.66	0
	...	2	4	2	2	2	3	2	3	2	2	3	4	0.04		
<i>birella</i> ...	...	38	68	60	37	19	83	28	61	41	20	22	19*/32- 50	68/55 =1.2	0.66	+
	...	0	2	1	1	0	1	1	0	1	1	1	...	0.05		
<i>arona</i> ...	...	36	61	60	36	21	83	34	68	36	30	26	27	61/51 =1.2	0.59	+
	...	1	3	2	1	1	2	3	1	1	3	0	1	0.03		
<i>kalrata</i> ...	+	52	54	17	43	26	89	46	94	25	29	36	34	54/55 =0.98	0.47	0
	...	5	7	3	4	3	12	5	11	8	3	2	2	0.06	0.02	
<i>ganmonsi</i> ...	0 †	33	51	22	35	21	82	39	77	23	25	29	26	51/46 =1.11	0.50	0
<i>ligula</i> (Radford)	+	39	52	14	34	22	58	39	71	9	35	38	35	52/50 =1.04	0.65	0
	...	8	10	5	4	4	6	4	5	4	8	8	7	0.07		
<i>punctata</i> (Radford)...	0	42	71	41	46	21	98	46	83	36	38	41	33	71/58 =1.2	0.6	0
	...	3	6	5	4	3	8	5	6	7	3	3	3	0.05	0.05	
<i>hipposideros</i> (Audy)	0	46	56	39	35	21	93	41	76	31	25	34	28	56/41.5 =1.35	0.49	0

+ indicates character is present or applicable

0 indicates absence of character

† indicates approximately, more or less

Ranges in microns above or below mean

* indicates dorsal setae become progressively longer
in conspicuous row

Summary

In connection with studies on Scrub Typhus in Malaya, North Burma, and India, 9 species of chiggers of the subgenus *Schöngastiella* have been collected. Of these, 7 are new and are described and illustrated in detail. The commonest species found in Assam and North Burma is *Gahrlipeia* (*Schöngastiella*) *ligula* (Radford). This is a characteristic parasite of *Rattus* in scrub terrain, although at times occurring on a variety of rodents, insectivores and carnivores. It was rarely collected in or near primary jungle. *Gahrlipeia* (*Schöngastiella*) *punctata* (Radford) was collected from 60 small mammals in Assam and North Burma. The great majority of hosts of this species were shrews. The only chiggers of this subgenus found in Malaya are *G. (S.) hipposideros* (Audy), *G. (S.) arona* n. sp. and *G. (S.) birella* n. sp. The two latter species are unique in possessing an anal plate. The following new species were found in Assam and Burma : *G. (S.) liota*, *G. erula*, *G. helata* and *G. gammonsii*. Of these *G. erula* is a parasite of *Rattus*, while the other three apparently infest shrews. *G. kalrata* n. sp. was collected from a mouse in Kashmir.

Chiggers of the subgenus *Schöngastiella* are relatively uncommon as compared with such trombiculids as *Trombicula deliensis* Walch, *T. fulleri* Ewing, and *Euschöngastia indica* (Hirst). Despite intensive collecting, involving hundreds of hosts and thousands of chiggers, some of the new species are represented only by one to three specimens. This group of mites is remarkably uniform insofar as concerns the setae of the palpal and the sensory setae of the legs, taxonomic characters of specific value in other genera.

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MALAYSIAN PARASITES VII

NEW GENERA AND SPECIES, APPARENTLY OF APOLONIINAE (ACARINA, LEEUWENHOEKIIDAE), FROM THE ASIATIC-PACIFIC REGION

By

H. WOMERSLEY

The subfamily Apoloniinae was established in 1947 by Wharton to include the genera *Apolonia* Torres and Braga and *Womersleyia* Wharton. His diagnosis of the subfamily was as follows: "Trombiculids with seven segments on all legs, one seta on coxae I, an anterior-median projection of the scutum, stigma and tracheae present, numerous ventral setae between the posterior coxae, and the posterior lateral scutal setae not on the scutum."

Wharton, aided by Fuller (1952, p. 90) later included *Sauracarella* Lawrence 1949, and gave the following diagnosis: "Trombiculids whose larvae have all legs composed of seven segments, and have paired, submedian, anterior, scutal setae, or an anterior, median, scutal projection or both. Sensillae expanded or attenuated."

In the present paper, the writer includes six additional genera, *Cockingsia* nov., *Audyana* nov., *Mackerasiella* nov., *Grossia* nov., *Nothotrombicula* Dumbleton and *Womersleyia* Radford. This is a heterogeneous assemblage of genera, but on larval characters they would be included in an expanded subfamily Apoloniinae, a concept which the writer believes to be useful at the present stage of knowledge. A clear line cannot at present be drawn between the Leeuwenhoekiidae, a family largely founded on larval characters, and the Trombidiidae, largely founded on adult characters. Until such time as the species discussed below are reared to the nymphs and adults, and comparisons made with related members of the Trombidiidae, placing them in the Apoloniinae *sensu lato* must be regarded as no more than tentative. This opportunity is nevertheless taken to describe these genera and species so that they will be available for consideration while our understanding of the Leeuwenhoekiidae is developing. The genus *Audyana* nov., for example, was at first considered as most nearly related in the larval stage to the Apoloniinae, but nymphs which have subsequently been bred show that this is a Trombelline genus near *Trombella*, in the family Trombidiidae. The relationships between such genera and those of the Apoloniinae require a great deal of study.

Key to Genera of Larvae from the Asiatic-Pacific region

1. Legs I 7-segmented, II and III 6-segmented, tarsal claws simple, no empodium. 2
Legs all 7-segmented. Tarsal claws variable 4
2. Scutum triangular, with pronounced snout-like anterior process bearing the two AM setae. Setae on coxae II and III and on femur of palpi normal. Sensillae filamentous and nude. Palpal claw bifurcate, tarsus small.
Gen. *Cockingsia* nov.
- Scutum without any anterior process 3
3. Scutum wider than long, more or less rectangular. Coxae II and III as well as maxillae and femora of palpi with short claviform peg-like setae. AM and AL setae also claviform and peg-like. Sensillae long and narrowly lanceolate with fine indistinct ciliations. Palpal tarsus apically with 2 long strong spines.

Gen. *Audyana* nov.

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Scutum longer than wide, tongue-shaped with additional setae behind PL; AM absent; SB wide apart and near to AL. No coxal, palpal or scutal peg-like spines as in above. Sensillae long and fine, nude. Palpal tarsus long, with two strong terminal spine-like setae. Chelicerae short and hook-like

Gen. *Mackerrasiella* nov.

4. Tarsal claws single, without empodium 5
Tarsal claws paired, with median empodium; PL setae placed on scutum 6
5. Scutum with pronounced antero-median process, bearing 2 AM setae; AL and PL setae strongly dentate; with an aberrant crista. Sensillae filamentous and nude. Palpal claw bifurcate and strongly hook-like.

Gen. *Neotrombidium* Leonardi 1901
= *Monunguis* Wharton 1938. (*Adult*)*

Scutum without anterior median process or crista. AM absent. AL and PL normal with short ciliations. Sensillae ciliated distally. Tarsi with a pair of spatulate setae flanking claw. Palpal claw with 4 strong sickle-like prongs.

Gen. *Grossia* nov.

6. Without AM setae. Scutal setae normal. Coxal setae short, stout and peg-like.
Gen. *Nothotrombicula* Dumbleton 1947.

With 2 AM setae. Scutal setae fairly short, stout and peg-like with fine distal barbs. Coxal setae normal.

Gen. *Womersleyia* Radford 1946.

Genus *Nothotrombicula* Dumbleton 1947

Trans. roy. Soc. N.Z., 1947, 76, 41.

Scutum with anterior median process but no anterior median setae. Sensillae long and filamentous and nude. Tarsi with paired claws and median claw-like empodium; legs all 7-segmented; coxae I with 2, II and III with 1 short, stout, peg-like setae.

Type *Nothotrombicula deinacridae* Dumbleton.

Nothotrombicula deinacridae Dumbleton 1947 (figs. 1 A-H).

Trans. roy. Soc. N. Z., 1947, 76, 411, figs. 8-10.

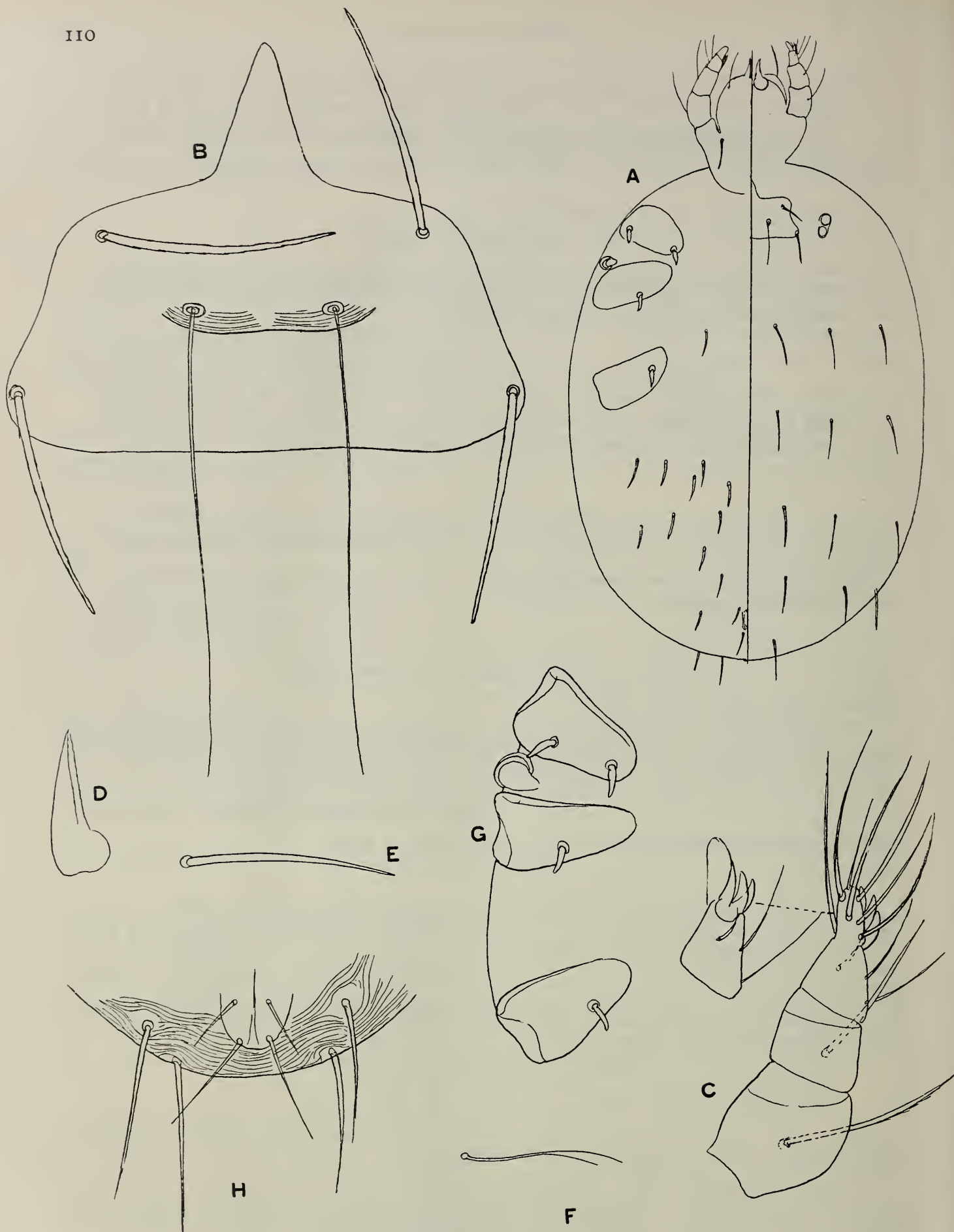
Redescription of Larvae.—Size large, oval; length to 1200 μ , width to 660 μ . Scutum as figured, transverse with PW greater than AW, and with an acute triangular antero-median process; AM wanting, AL and PL subequal, sensillae filamentous, nude, and bases slightly in front of midline between AL and PL, with a line posterior and fine transverse striations between. Eyes 2+2. Chelicerae with teeth? Galeal setae? Palpi rounded laterally, tibial claw short, stout, trifurcate; seta on femur lightly ciliated apically, genu and tibia all nude; tarsus small. Dorsal setae stout, only slightly ciliated, tapering, 26 in number and arranged 6.6.6.6.2. Ventrally, with a pair of normal setae on maxillae, 2 short peg-like setae on coxae I, one similar seta on coxae II and III, a pair of normal setae between coxae III and therefore 10.6.2.2.2. plus 2 stout spines on lobes of anus. Legs: I 200 μ long, II 185 μ , III 180 μ .

The Standard Data for the type and 2 paratypes as given by Dumbleton are :

AW 105.0, 105.0, 105.0, PW 155.1, 161.7, 165.0, SB 42.9, 49.5, 49.5,
ASB 49.5, 49.5, 49.5, PSB 42.9, 42.9, 42.9, A-P 50.4, 56.1, 59.4,
AL 75.9, 72.6, 82.5, PL 82.5, 82.5, Sens. 138.6, 141.9, 155.1.

Loc. and Host.—This very interesting genus and species was described from specimens parasitic on the Giant Weta or King Cricket of New Zealand (*Deinacrida rugosa*?) from Mt. Peel, Nelson, New Zealand.

* The genus *Neotrombidium* is based on adult material (genotype *Neotrombidium barringtonense* Hirst, 1928). *Monunguis* Wharton, 1947, was based on larvae. In correspondence with me, and in a brief note (1947) Wharton has indicated the synonymy of *Monunguis* with *Neotrombidium*. The nearest relatives of this genus are the genera here placed in the Apoloniinae. For the sake of completeness and for comparison with the others, *Neotrombidium* is provisionally included in the above Key under the characters of the larvae of *Monunguis* syn. Discussion of this genus is however reserved for a subsequent paper.



1. *Nothotrombicula deinacridae* Dumbleton, 1947

A, dorsal and ventral halves of larva; B, scutum ($\times 500$); C, palp; D, chelicer; E, dorsal seta; F, maxillary seta; G, left coxae; H, apex of abdomen ventrally. (Mainly after Dumbleton).

Remarks.—The author compares the genus with *Hemitrombicula* Ewing, but as Wharton has shown, the latter is not in any way associated with the Trombiculids. The closest relationship of *Nothotrombicula* is with the various genera of the subfamily Apoloniinae, but it is near to *Audyana* n. gen. in the form of the scute, yet differs in the leg-segmentation, the form of the AL scutal setae, and the absence of any AM.

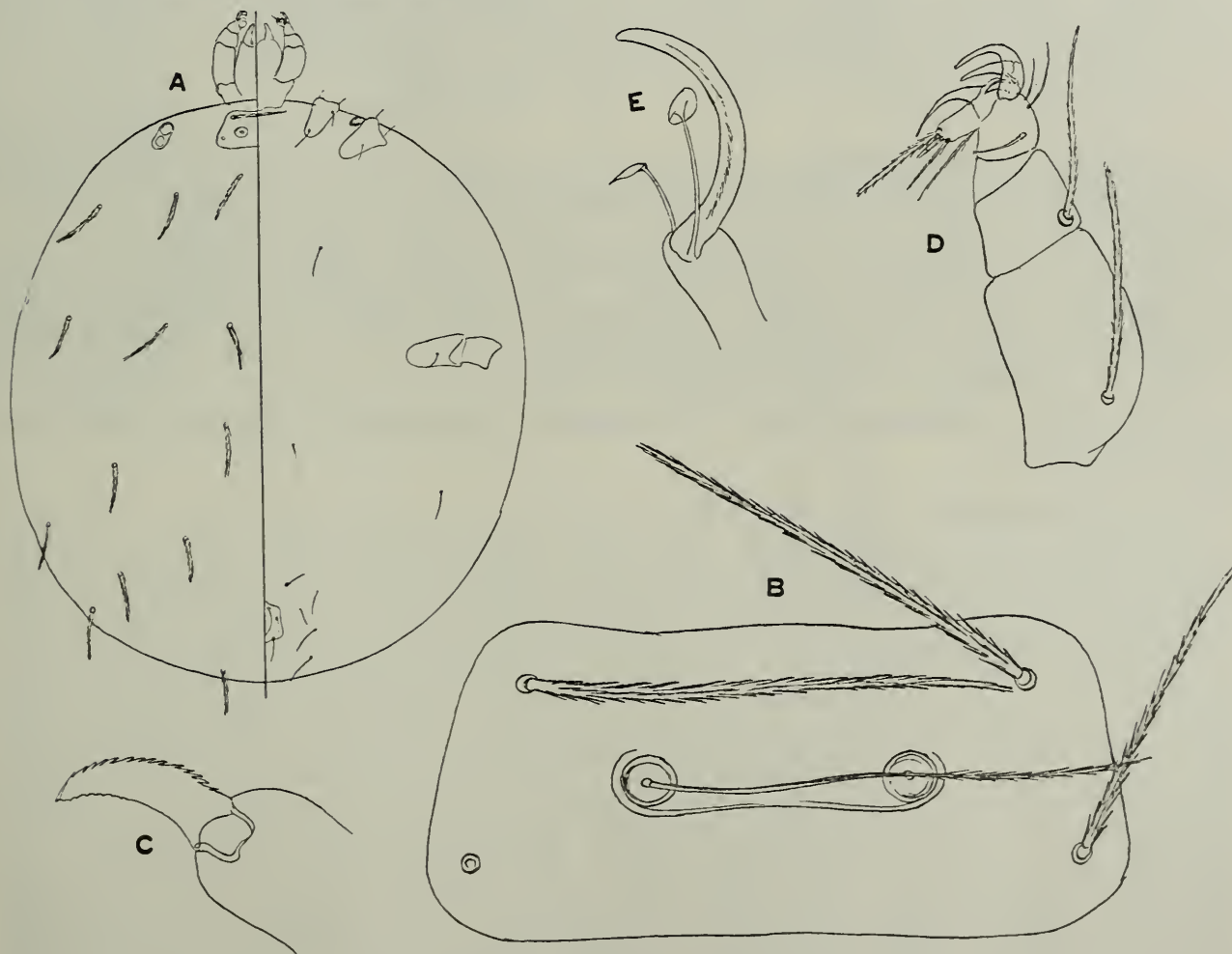
Genus **Grossia** nov.

Belonging to the subfamily Apoloniinae *sensu lato* of the Leeuwenhoekiidae, and distinguishable by the absence of AM scutal setae, by the tarsi of all legs being furnished with a single claw, and by a pair of shorter apically spatulate tenent setae.

Type *Grossia onychia* n. sp.

Remarks.—As given in the generic diagnosis this remarkable genus appears to belong to the subfamily Apoloniinae of the Leeuwenhoekiidae in that all the legs are 7-segmented. It comes closest to the genus *Neotrombidium* but differs from this and all other genera of the family in the absence of the AM scutal setae and the presence of paired spatulate setae on each tarsus at the base of the single claw, a feature common to the Tetranychidae, but hitherto unknown in the Trombiculidae or Leeuwenhoekiidae.

The genus is dedicated to the finder.



2. *Grossia onychia* n. gen., n. sp.

A, dorsal and ventral halves of larva; B, scutum ($\times 450$); C, chelicer; D, palp; E, tip of tarsus.

Grossia onychia n. sp. (figs. 2 A-E).

Description of Larva.—Size large, length (engorged) 1500 μ ; width 1300 μ . Shape like a small pea. Colour in life? Scutum as figured, large, triangular, with apex pointing forwards; AM setae absent, AL setae behind the midlength; PL near the posterior corners; sensillae in between AL and PL, very long and moderately thick, with short adpressed barbs or ciliations on distal half; AL and PL setae long, thick and shortly ciliated or barbed. Eyes 2+2, on ocular shield, and nearer to lateral body margins than to scutum. Chelicerae as figured, with a few fine teeth distally on inner (dorsal) edge, and fine teeth all the length of outer edge. Galeal setae short and simple. Palpi as figured, tibiae with curved short bifurcate claw; setae on femur and genu, thick and shortly ciliated; setae on tibia and tarsus not ascertainable. Dorsal setae thick and shortly ciliated, arising from small platelets, 26 in number, arranged 6.6.6.6.2. from 156 μ long anteriorly to 195 μ long posteriorly. Ventrally, a pair of short setae anteriorly on maxillae, a pair of short setae on coxae I, and one seta on each of coxae II and III, a pair of short apparently simple setae between coxae III and thereafter 4 setae, followed by five setae on each side of anus; these ventral setae gradually lengthening and apparently nude. The anus is furnished with two pairs of setae. Legs all 7-segmented, I 540 μ long, II 540 μ , III 600 μ ; tarsi I and II without any dorsal rod-like seta, III without any long nude seta; all tarsi furnished with a single strong claw, on each side of which is a shorter spatulate seta.

The Standard Data for the type are :

AW 100.0, PW 156.0, SB 73.0, ASB 143.0, PSB 20.0, SD 163.0, A-P 55.0.

AL 112.0, PL 84.0, Sens. 168.0.

Loc. and Host.—A single specimen attached to an adult Trombidiid (*Chyzeria australiense* Hirst) from the Ottway Ranges, Victoria, 1951 (*G. F. Gross*).

Genus Mackerrasiella nov

Shape globose, with leg I 7-segmented, II and III 6-segmented, tarsal claws single, no empodium. Scutum ill defined, overlapped with longitudinal striations, with no AM, 2 AL and 2 PL and two small additional setae at posterior end; sensillae filamentous. Eyes 2+2, widely separated and posterior the smaller. Chelicerae hook-like.

Type *Mackerrasiella globus* n. sp.

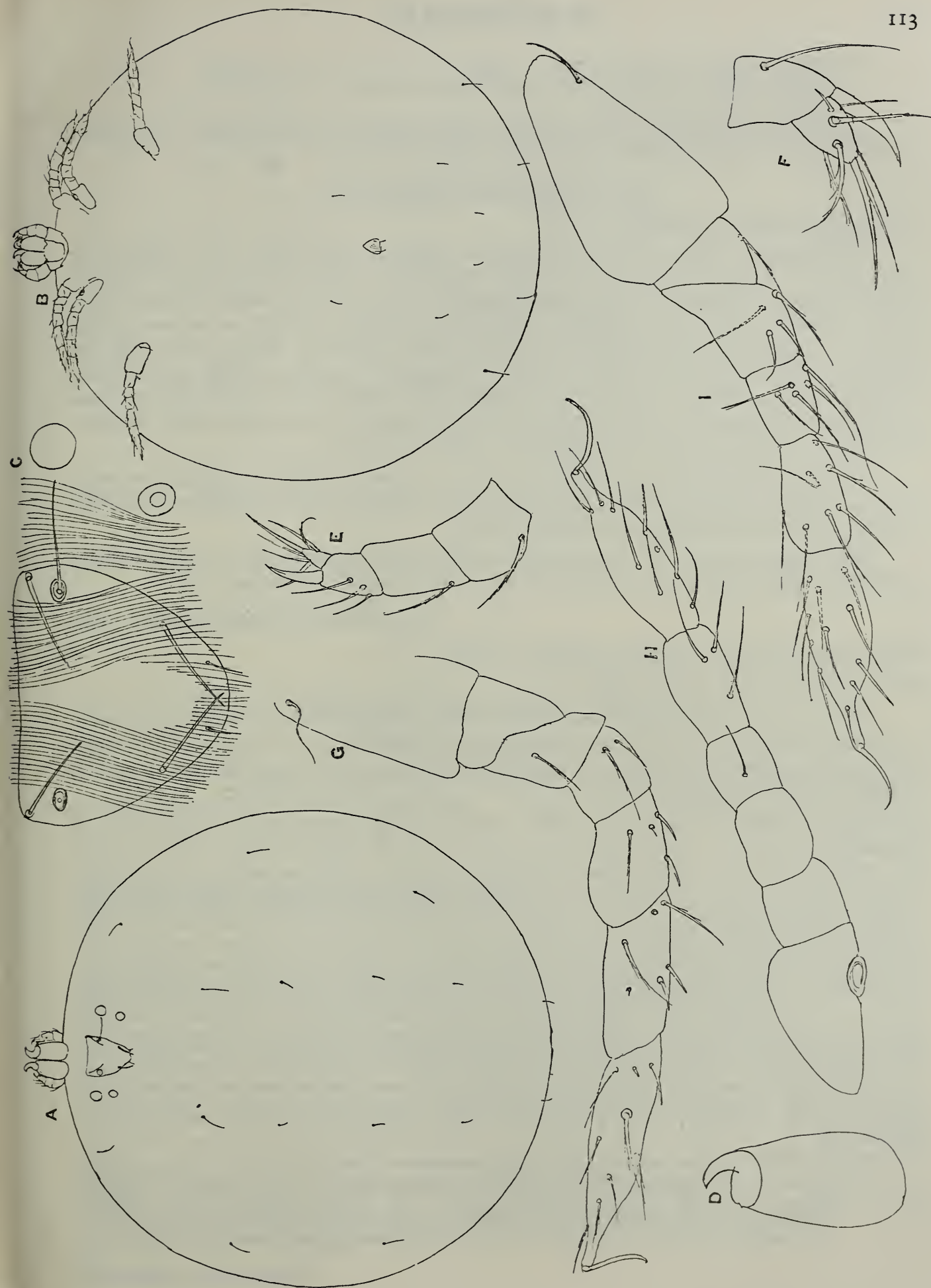
Remarks.—In the segmentation of the legs this new genus may be placed in the subfamily Apoloniinae of the Leeuwenhoekidae, which already contains rather a heterogeneous collection of genera. In the absence of AM scutal setae, and the slight posterior prolongation of the scutum and the additional two small posterior setae it might equally well be placed in the Gahrlepiinae of the Trombiculidae. The presence of single tarsal claws, however, also allies it with the Apoloniinae. Altogether its true relation is obscure and will remain so until it becomes possible to correlate the larvae with nymphs or adults.

This genus is dedicated to Mrs. J. M. Mackerras, Parasitologist, Queensland Institute of Medical Research.

Mackerrasiella globus n. sp. (figs. 3 A-I).

Description of Larvae.—Shape globose, when mounted and compressed perfectly round. Length of idiosoma (engorged) 845 μ , width 845 μ . Scutum small, margins ill defined, and overlapped by longitudinally striated cuticle; no AM setae present, anterior margin between AL lightly concave; sensillae filamentous, apparently nude and bases close to AL, wide apart, SB being only a little less than distance between AL; PL still nearer together; scutum posteriorly behind PL with two short fine additional setae, 11 μ long; scutal setae apparently nude. Eyes large, 2+2, widely separated and posterior the smaller, anterior in line with SB, and posterior about in line with PL, posterior eye with strongly refringent centre. Mandibles large, with the chelicerae hook-like and non-serrate. Galeal setae? Palpi as figured, tibial claw bifurcate; setae on femur and genu relatively short with short indistinct barbs, on tibia all 3 setae nude, tarsus rather long and cylindrical, with a long strong apical seta, and no sensory rod, as figured. Dorsal setae sparse and apparently nude; two humeral setae 45 μ long, then a row of four 51 μ long, followed by submedial 20 μ long, then four of which the laterals are 45 μ long and the submedials 20 μ , then two submedials 20 μ long, and apically two more 20 μ long. Ventrally: apparently no setae on maxillae, one short seta on the tip of the evanescent coxae I, none on coxae II and one short seta towards apex of coxae III; no setae between any coxae; a pair of short 20 μ setae in front of anus; anus itself on a small triangular shield and carrying two small setae; behind anus 8 small setae. No true spiracles between gnathosoma and coxae I apparent. Legs relatively short, I 7-segmented, II and III 6-segmented; leg I 240 μ long, II 195 μ long, III 208 μ , long; tarsal claws only one, and no empodium present; setae of specialised nature on legs as follows: I, 2 genulae and 1 micro-genuala, 2 tibialae and 1 microtibiala, 1 tarsala and 1 microtarsala; II, one tarsala only; III with two femoralae, one whip-like mastigenuala; no sensory rod on any tarsi.

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3. *Mackerrasiella globus* n. gen., n. sp.

A, dorsum, and B, venter, of larva; C, scutum and eyes ($\times 530$); D, chelicer; E, palp; F, palpal tibia and tarsus further enlarged; G, leg I; H, leg II; I, leg III.

The Standard Data for the type are :

AW 70.0, PW 42.0, SB 61.6, ASB 14.0, PSB 58.8, SD 72.8, A-P 50.42.

AL 30.8, PL 29.4, Sens. 33.6.

Loc. and Host.—Described from the type and paratype attached to two Dolichopodid flies collected in a light trap at Merbein, Victoria, 2.xii, 1951. (Mrs J. M. Mackerras).

Genus *Womersleyia* Radford 1946

Parasitology, 1946, 37, 48-51, figs. 19-23.

Re-diagnosis of Genus.—Leeuwenhoeekiidae, subfamily Apoloniinae, with legs all 7-segmented. Tarsal claws paired, with median empodium. With 2 AM setae present and PL on the scutum. Scutum with strong antero-median conical process on which are the two AM setae. Scutal setae stout and spine-like with distal fine ciliations, but PL not so stout as AM and AL. Sensillae fine and filamentous, with fine distal ciliations. Palpal claws single but bifid and deeply cleft, short and curved; tarsus terminating in two stout, straight spines or setae with fine distal ciliations; as well as several long finely ciliated setae. Chelicerae short and curved, non-serrate, with a small apical tricuspid cap. Eyes 2+2, on ocular shields, posterior the smaller, and placed close to posterolateral corners of scutum.

The above re-diagnosis of the genus is based on a paratype specimen kindly given to me by Dr. Radford, and takes into account the various characters now considered of generic importance in the taxonomy of this family of mites.

Both Radford and R. F. Lawrence, 1949, placed the genus in the Leeuwenhoeekiinae Womersley 1944, but it more naturally belongs to the subfamily Apoloniinae.

Type *Womersleyia minuta* Radford, 1946.

Womersleyia minuta Radford, 1946 (figs. 4 A-G).

Parasitology, 1946, 37, 51, fig. 19-23.

This very interesting species was described from specimens at first collected from mud in a Pandanus swamp from Gan Island, Addu Atoll, in the Maldives, 20. xii. 1944, and later found to be parasitic under the wings of grasshoppers belonging to the three families Acrididae, Tetrigidae and Tettigoniidae.

The following re-description is from a specimen from grasshoppers given to me by Dr. Radford.

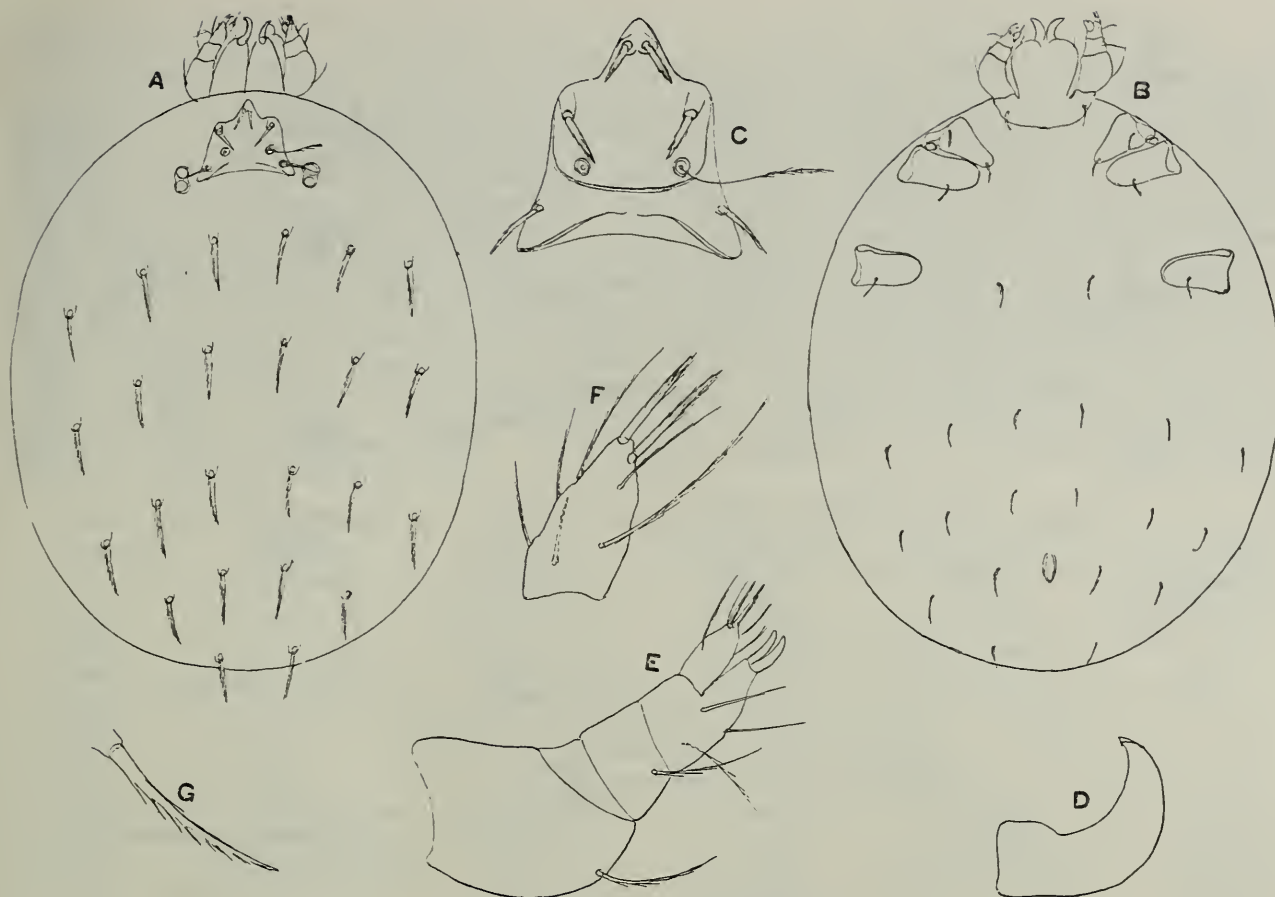
Re-description of Larvae.—Shape oval. Colour in life reddish: Length (engorged) 400 μ , width 335 μ . Scutum as figured, wider between PL than between AL; anteriorly with a strong and pronounced conical process which carries the two AM setae; postero-lateral corners produced, and posterior margin lightly concave; the scutal setae are short, stout and spine-like with short fine distal ciliations and arise from strong tubercles; sensillae fine and filamentous, ciliated distally with the bases in a line midway between lines of AL and PL; from the antero-lateral corners a strong line runs posteriorly to behind the sensillae bases, and from the posterior corners also a strong line runs anteriorly meeting and thinning out medially in line of PL. Eyes 2+2, large and on ocular shields close to the postero-lateral corners of the scutum. Chelicerae small, but rather strongly curved, non-serrate, with only an apical tricuspid cap. Galeal setae nude. Palpi stout, tibial claw rather short, bifid, nude and deeply cleft and lightly curved; setae on palpal femur and genu fine and shortly ciliated, on tibia, only the ventral branched; the tarsus with a pair of strong thick apical spines or setae which are distally finely ciliated; as well as several normal long and ciliated setae. The dorsal setae are 6.6.6.4.2. to 34 μ long. Ventrally, with a pair of ciliated setae on maxillae, two on coxae I, and one on coxae II and III, a pair between coxae III, and thereafter ca. 6.6.4.2. varying from 17 μ anteriorly to 24 μ posteriorly. Legs: I 188 μ long, II 160 μ , III 206 μ ; no long nude setae on tarsi or metatarsi III.

No trace of trachea or true spiracles between gnathosoma and coxae I.

The Standard Data for the above paratype compared with those given by Radford (in parentheses) are:

AW 33.5 (34.0), PW 50.25 (55.0), SB 26.8 (34.0), ASB, to base of process 23.45, to apex of process 39.85 (40.0), PSB 23.45 (17.0), SD to base of process 46.9, to apex of process 63.3 (60.0), A-P 26.85 (25.0), AM 13.4 (17.0), AL 16.75 (17.0), PL 16.75 (20.0), Sens. 33.5 (51.0).

STUD. INST. MED. RES.



4. *Womersleyia minuta* Radford, 1945

A, dorsum, and B, venter, of larva; C, scutum ($\times 390$); D, chelicer; E, palp; F, palpal tarsus further enlarged; G, dorsal seta.

Genus *Cockingsia* nov.

With the characters of the Leeuwenhoekiidae, subfamily Apoloniinae, with leg I 7-segmented and legs II and III 6-segmented. Scutum roughly triangular with apex anterior as a pronounced process carrying the two AM setae. Tarsal claws single, no empodium. Coxae I with 2 setae. Palpi, except the femur, cylindrical; tibia with paired or bifurcate strong and slightly curved claws, tarsus normal and small. Scutal setae stiff, rod-like and minutely serrate. Stigmata and tracheae present.

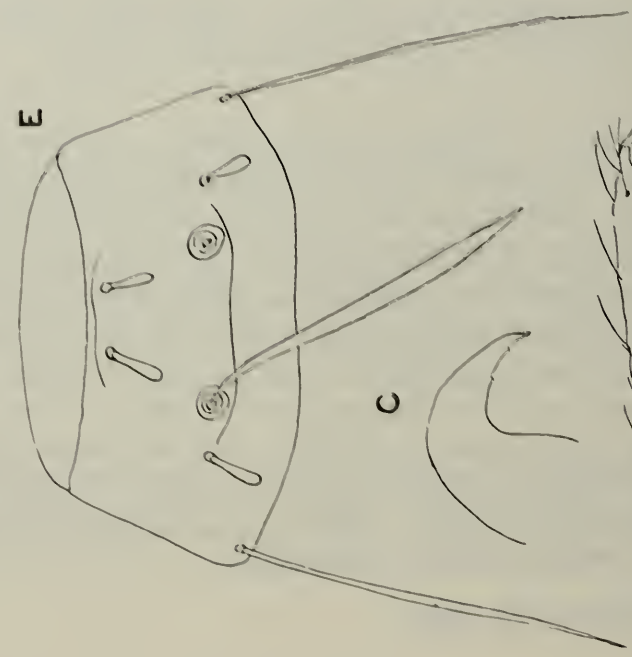
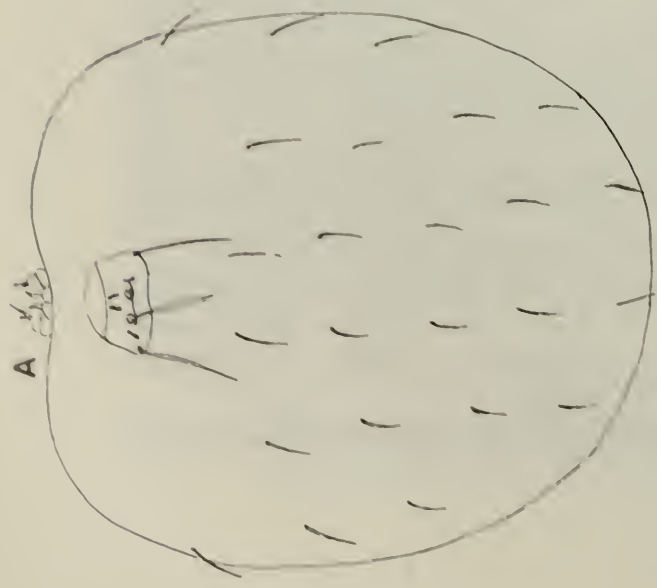
Type *Cockingsia tenuipes* n. sp.

Remarks.—This genus which in the form of the scutum is closely related to *Audyana* n. g., *Womersleyia* Radford and *Neotrombidium* Leonardi (= *Monunguis* Wharton) is dedicated to Mr. K. L. Cockings, a former member of the Colonial Office Unit in Malaya.

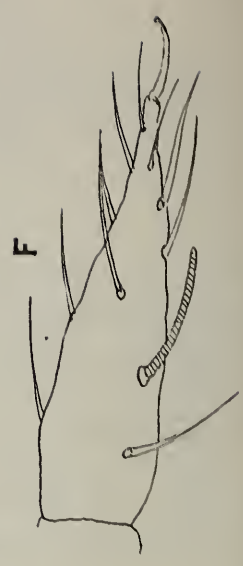
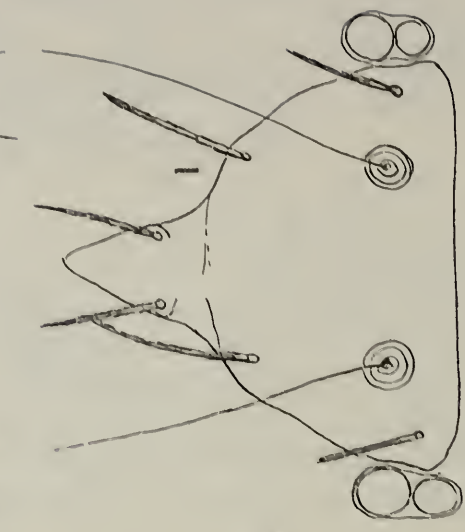
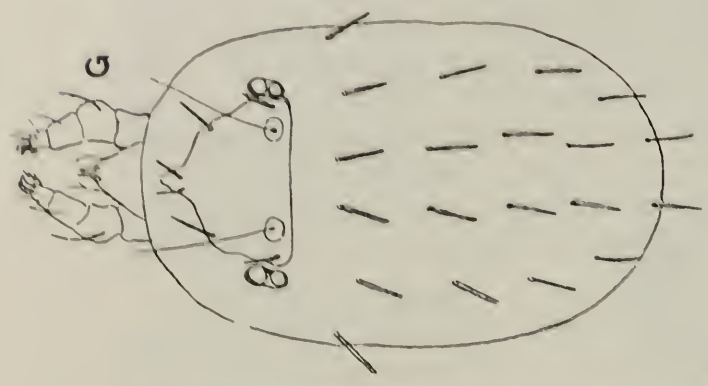
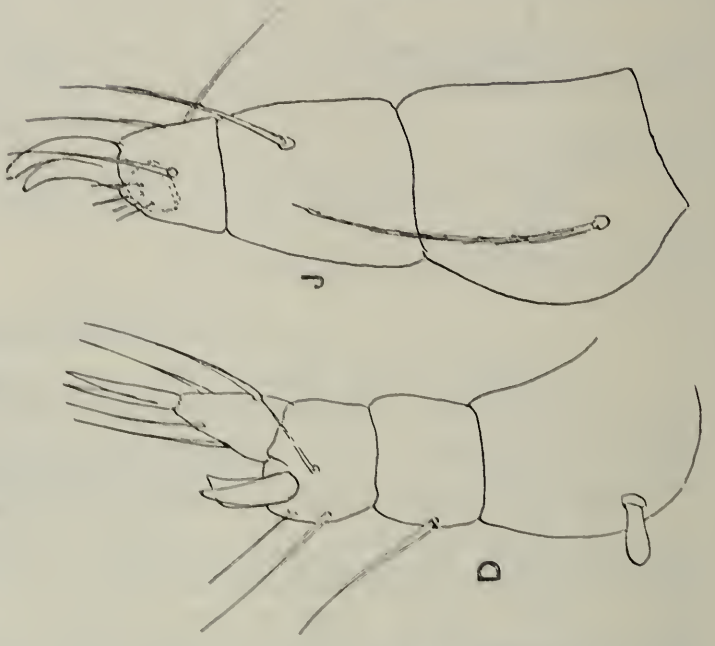
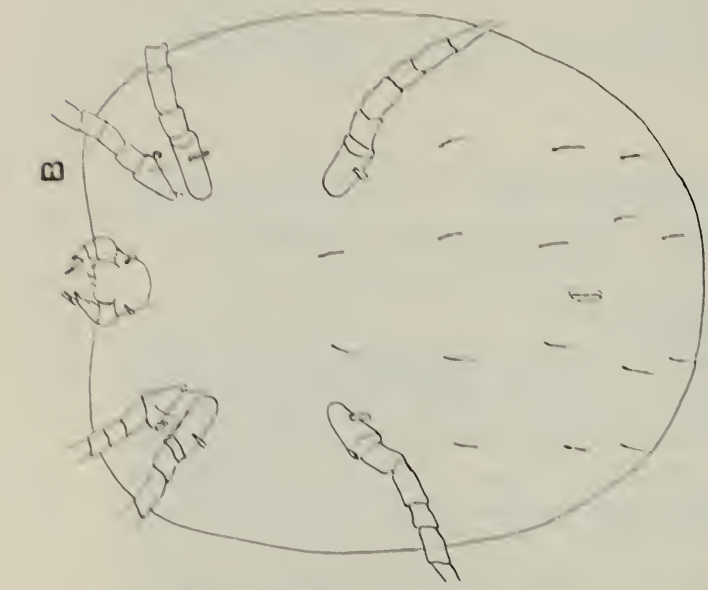
The genus is perhaps nearest to *Neotrombidium* (*Monunguis*) in having single tarsal claws and nude filamentous sensillae, but differs in the legs II and III being only 6-segmented, and in the less curved palpal claws, as well as in the absence of any sign of an incipient crista.

In the leg segmentation it agrees with *Audyana* n. gen., but differs in the form of the scutal setae, and in having single tarsal claws, as well as in the form of the setae on the maxillae and on coxae II and III. Also the palpal tarsus is normal and without the terminal spines of *Audyana*, and the palpal claws are not short and stumpy.

From *Womersleyia* it differs in the single tarsal claws, and the more specialised palpal tarsus, as well as the leg segmentation.



5. *Audyana thompsoni* n. gen., n. sp.
A, dorsum, and B, venter, of larva; C, tip of chelicer; D, palp;
E, scutum ($\times 500$); F, tarsus I.



Cockingsia tenuipes n. gen., n. sp.
G, dorsum, and H, venter, of larva; I, scutum ($\times 500$); J, palp;
K, tibia and tarsus I.

Cockingsia tenuipes n. sp. (figs. 5 G-K).

Description of Larvae.—Shape oval but with sides somewhat flattened and when fully engorged with a slight medial constriction. Length (unfed) 260μ , width 156μ ; fully engorged, to 715μ , and 480μ respectively. Scutum roughly triangular with apex directed forward as an anterior median process bearing the 2 AM setae; sensillae filamentous and nude, their bases large, widely separated and in line of PL; scutal setae stiff and rod-like with indistinct serrations. Eyes 2+2, large, on ocular shields and closely adjacent to postero-lateral corners of scutum. Chelicerae small, non-serrate, and with only the apical cap. Galeal setae short, fine and nude. Palpi as figured, femur outwardly slightly rounded with a long shortly ciliated seta; genu cylindrical with a nude seta, tibia short with all 3 setae nude, and a bifurcate strong slightly curved claw; tarsus small with fine non-specialised setae. Dorsal setae short from 32μ anteriorly to 42μ posteriorly, rod-like with indistinct serrations, 20 in number, and arranged 2.4.4.4.2. Ventrally, no setae could be observed on the maxillae; coxae I with 2 long fine setae, II and III with 1 such seta; a pair between coxae III and then 4.2.2.2., the median two the first four being close to the anus, and varying in length from 16μ anteriorly to 39μ posteriorly. Legs long and unusually slender, I (to tip of claw) 312μ , II 312μ , III 338μ ; tarsi I and II with sensory rod, III without any long nude seta; claws long, curved and single. Empodium absent. Spiracle between gnathosoma and coxae I present, but only beginning of tracheae observed.

The Standard Data for the type (unfed) and 13 paratypes (fully engorged) are as follows :

	Mean.	Standard Deviation.	Theoretical Range.	Observed Range.	Coeff. of Variation.
AW	... 44.6 ± 0.55	... 2.04 ± 0.39	... 38.5-50.7	... 42.0-47.6	... 4.6
PW	... 71.6 ± 0.64	... 2.38 ± 0.45	... 64.45-78.75	... 67.2-75.8	... 3.3
SB	... 42.4 ± 0.50	... 1.86 ± 0.35	... 36.8-48.0	... 39.2-44.8	... 4.4
ASB	... 67.2		No variation recorded.		
PSB	... 14.0		No variation recorded.		
SD	... 81.2		No variation recorded.		
A-P	... 36.2 ± 0.46	... 1.72 ± 0.33	... 31.0-41.4	... 33.6-39.2	... 4.8
AM	... 29.8 ± 0.47	... 1.77 ± 0.33	... 24.5-35.1	... 25.2-30.8	... 6.0
AL	... 33.0 ± 0.52	... 1.96 ± 0.37	... 27.1-38.9	... 28.0-36.4	... 5.9
PL	... 22.6 ± 0.20	... 0.75 ± 0.14	... 20.35-24.85	... 22.4-25.2	... 3.3
Sens	... 75.6		No variation recorded.		

Loc. and Host.—This genus and species is described from specimens taken from the wings of a giant longicorn beetle from Sungei Buloh, Selangor, Malaya, 17. viii. 1948. (*J. R. Audy*).

Remarks.—The affinities of this species are discussed under the generic description.

Family TROMBIDIIDAE Leach, 1815

Subfamily TROMBELLINAE Thor, 1935

Genus *Audyana* nov.

Scutum somewhat rectangular, with 2 AM, 2 AL, and 2 PL setae, of which the AM and AL setae are modified to form short claviform organs, the AL being situated in line with sensillae bases and lateral to these, but nearer than to the lateral margins; PL setae long and normal but mid-shaft very slightly thickened; sensillae long and narrowly lanceolate with fine indistinct ciliations; anterior scutal margin concave, without median process, but extending in front and the whole way across is a wide more or less hyaline part with its anterior margin flattened (whether this is the anterior part of the scutum is uncertain). Legs: I 7-, II and III 6-segmented, tarsi furnished with only a single claw, and no empodium; coxae I with 2 fine, ciliated normal setae, II and III with 1 short claviform setae as in AM and AL; palpi stout, tibial claws short, equal, stumpy; maxillae and femora with a stout short claviform seta, genu with a long straight nude seta; tibia with 3 setae nude and straight; tarsus conical over-reaching claws, and apically with 2 long strong spines and with 4 to 5 nude setae. Chelicerae strongly curved, in addition to a minute apical cap, with two small subapical dorsal teeth. Galeal setae ?absent. Eyes apparently absent. No stigmata and tracheae observed. Dorsal and ventral setae tapering, short and indistinctly ciliated.

In the general conformity of the scutum this genus might have come in the subfamily Apoloniinae of the Leeuwenhoeekiidae, particularly in having leg I 7-segmented. It differs from the other genera of the subfamily in that *only* Leg I is 7-segmented. In the palpal claws it resembles *Womersleyia* Radford, and in the single tarsal claws it closely resembles to *Neotrombidium* Leonardi (*Monunguis* Wharton).

Nymphs of this species have however been bred by Messrs. Lee Fatt-Hing and Aman bin Mahmood of the Colonial Office Research Unit, and these are clearly related to *Trombella* Berl. in the subfamily Trombellinae. A description of the nymph, together with a review of the whole subfamily, is to be published elsewhere.

The genus is named after Dr. J. R. Audy, leader of the British Colonial Office Research Unit in Malaya.

Type *Audyana thompsoni* n. sp.

***Audyana thompsoni* n. sp. (figs. 15 A-F).**

Description of Larvae.—Size (engorged) to 650 μ , width to 450 μ . Shape oval. Legs: I 285 μ long, II 235 μ , III 260 μ . Scutum as figured with paired AM, AL and PL setae and 2 sensillae; anterior margin concave, apparently without any median process, but with a deep hyaline band extending the whole width of scutum; AM and AL setae modified to short claviform bodies, and AL not at the antero-lateral corners but placed close to, lateral to and in line with sensillae bases; PL long and very narrowly lanceolate; sensillae longer and distinctly lanceolate. Eyes apparently absent. Palpi stout, tibia with two short straight claws, maxillae and femora with short claviform setae; genu with a long nude seta; tibia with 3 nude setae; tarsus conical over-reaching tibial claws, with two long straight apical spines and 4 or 5 straight nude setae. Chelicerae strongly curved, with a minute spical tricuspid cap, and two small subapically dorsal teeth. Dorsal seta tapering, finely but indistinctly ciliated, arranged 2.6.6.4.4.2 to 58 μ long. Ventrally, 2 fine ciliated setae on coxae I, a single claviform seta on coxae II and III, a pair of fine ciliated setae between coxae III, then 4.4.4.2 setae. Legs: I 7-segmented, II and III 6-segmented; all tarsi with only a single claw; no long nude seta on tarsi III.

THE STANDARD DATA FOR 8 SPECIMENS ARE :

	Mean.		Standard Deviation.		Theoretical Range.		Observed Range.		Coeff. of Variation.
AWS†	71.05+1.05	...	2.97+0.74	...	62.15-79.95	...	70.0-78.4	...	4.1
AW†	57.05+0.74	...	2.08+0.52	...	50.8-63.3	...	36.0-61.6	...	3.6
PW	93.4+0.94	...	2.65+0.66	...	85.4-101.4	...	89.6-98.0	...	2.8
SB	33.6+0.53	...	1.50+0.37	...	29.1-38.1	...	30.8-36.4	...	4.4
ASB	30.45+0.35	...	0.99+0.25	...	27.5-33.4	...	28.0-30.8	...	3.2
PSB	16.8	...		...	No variation recorded				
SD	47.25+0.35	...	0.99+0.25	...	44.3-50.2	...	44.8-47.6	...	2.1
(A-P)S†	37.1+0.70	...	1.98+0.49	...	31.2-43.0	...	33.6-39.2	...	5.3
AM	11.2	...		...	No variation recorded				
AL	11.2	...		...	No variation recorded				
PL	84.0+1.59	...	4.49+1.12	...	70.5-97.5	...	78.4-89.6	...	5.3
Sens.	76.3+2.10	...	4.2+1.48	...	63.7-88.9	...	70.0-78.4	...	5.5

Loc. and Host.—Eight specimens (C.O.R.U. 4244-7) taken from the venter of the common giant black scorpion, *Heterometrus longimanus* (No. R 6049), Pahang Road, Ulu Gombak Forest Reserve, Selangor, Malaya, 14.iv.1949 (*J. R. Audy*). Many more specimens have been collected since.

Remarks.—This species is named for Lieut.-General Sir Treffry O. Thompson, K.C.S.I., C.B., C.B.E., K.H.P., D.M., D.P.H., formerly Director of Medical Services, Allied Land Forces, South East Asia, in recognition of his great encouragement of research on Scrub Typhus during World War II.

Audyana thompsoni is reported to occur in small numbers, usually attached near the pecten, on nearly half the specimens of *Heterometrus* collected from forest in Selangor. As already noted, nymphs have been bred out, enabling the species to be placed in the Trombellinae.

† In the above, AWS is the anterior width of the scutum, and AW is the width between the transposed AL setae/measured as defined for the Standard Data. Similarly (A-P)S is the distance between the antero-lateral corners of the scutum and the PL bases.

Summary

Three new genera and species, *Cockingsia tenuipes*, *Grossia onychia* and *Mackerrasiella globus* are described and their affinities are considered to be closest with the Apoloniinae Wharton. The genera *Nothotrombicula* and *Womersleyia* are re-described together with their type species, and likewise ascribed to the Apoloniinae.

Five genera are thus provisionally placed in the Apoloniinae pending further studies of related species as well as of nymphal and adult stages.

Another new genus and species, *Audyana thompsoni*, is described and placed in the family Trombidiidae, subfamily Trombellinae, with a note on the general affinities of the larva with the Apoloniinae.

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MALAYSIAN PARASITES VIII

ON THE VALIDITY OF THOSE GENERA OF TROMBICULIDAE (ACARINA) WITH POSTEROLATERAL SETAE OFF THE SCUTUM

By

H. WOMERSLEY

The number of Trombiculid genera characterised by having the scutum more or less reduced so that the posterior lateral scutal setae are placed off the scutum, has during the present decade been added to by many workers as our knowledge of this family of Acarina increases.

No fewer than nine species* referred to seven genera have been described as follows :

<i>Ascoschöngastia malayensis</i> (Gater 1932) ...	...	...	Malaya
<i>Tecomatlana sandovali</i> Hoffmann 1947 ...	...	...	Mexico
<i>Sauriscus ewingi</i> Lawrence 1949 ...	...	...	S. Africa
<i>Trisetica melvini</i> Traub and Evans 1950 ...	...	...	Burma
<i>Ascoschöngastia hungerfordi</i> Lipovsky 1951 ...	...	...	Burma
<i>Pseudoschöngastia hungerfordi</i> Lipovsky 1951 ...	...	...	N. America
„ <i>farneri</i> Lipovsky 1951 ...	...	...	N. America
„ <i>diazi</i> (Hoffmann 1947) Lipovsky 1951...	...	...	Mexico
<i>Anomalaspis ambiguus</i> Brennan 1952 ...	...	...	Venezuela

All the above possess the following generic features: (1) one AM and two AL scutal setae; (2) non-serrate chelicerae; and (3) a more or less, and either longitudinally or transversely, reduced scutum so that PL lies distinctly away from the scutal margin.

Other characters generally considered by acarologists as of generic or greater value are: (1) the leg-segmentation i.e., the division or otherwise of the femur, giving a 7-segmented or a 6-segmented leg; and (2) the form, filamentous, clavate, or globose, of the scutal sensillae.

Wharton *et al.* (1950) have proposed a classification of the Trombiculidae (incl. Leeuwenhoekiiidae) in which the subfamily Gahrlepiinae (sic. Walchiinae) is defined on the basis of leg I being 7-segmented and II and III 6-segmented. In their key this includes two genera, then given unnamed as in MS: one to be, but as yet not, described by H. S. Fuller for the species *Trombicula oudemansi* Walch 1922, the other, since described by Lipovsky (1951) as *Pseudoschöngastia*.

Both these, the species *oudemansi* and the genus *Pseudoschöngastia*, possess an AM scutal seta, whereas all the other genera listed by Wharton *et al* in the Walchiinae lack this seta.

Womersley (1952) confines the Gahrlepiinae (Walchiinae) to those forms not having an AM seta, a feature which from our present knowledge of the nymphal and adult stages is correlated with the occurrence of a dorsal stump-like process on the front tarsus in those later stages. None of the species placed in *Pseudoschöngastia* have yet been reared to the nymph or adult, but the nymph of *oudemansi* was described by Womersley (1952) and this does not possess such a tarsal process.

Thus while the Gahrlepiinae all appear, so far, to have the segmentation of the legs, 7-6-6, instead of the usual 7-7-7 in the Trombiculinae, the occurrence of odd forms with 7-6-6 in the latter subfamily is not of generic importance. In the reduction of the dorsal scutum with

* This paper was written before the species to be placed in a new subgenus of *Doloiisia* Ouds were found (see Audy 1953 this *Study* p. 159)

the resultant placing of PL off the scutum we have a gradual process from the species *malayensis* with the scutum of almost normal form and size and PL only slightly off the posterior corners, to the more reduced forms like *Sauriscus ewingi* in which the scutum ends well in front of PL and this seta is far removed from the scutal margin. This process of reduction of the scutum is the converse of what is found in many species of Gahrlepiinae, as well the genus *Novotrombicula* of the Trombiculinae, in which the scutum has become expanded posteriorly to embrace more and more of the dorsal setae.

Such being the case, the use of the number and position of the scutal setae does not appear to be generic value, and as pointed out by Womersley (1952) for the Gahrlepiinae, doubtfully of subgeneric value.

In 1952, Womersley synonymised the genera *Trisetica* Traub and Evans, and *Sauriscus* Lawrence with *Tecomatlana* Hoffmann†.

Now *Anomalaspis* Brennan also becomes a synonym. All these four genera have filamentous sensillae, and do not show features by which they can validly be separated from *Tecomatlana*.

In the larvae *Pseudoschöngastia* Lipovsky cannot be separated from *Ascoschöngastia*, which genus however can only be accepted as valid if it can be shown that characters exist in the nymph and/or adult stages which can be correlated with the presence on or off the scutum of the PL seta.

The genus *Ascoschöngastia* was erected by Ewing (1946) with *malayensis* as type on the basis of the non-serrate chelicerae. He did not, however, stress the off-scutal position of PLs, and clearly included all the species placed by other workers erroneously in the genus *Neoschöngastia* [which did not conform to the type *Neoschöngastia americana* (Hirst, 1921)]. Wharton *et al* (1951), however, would restrict the use of *Ascoschöngastia* to those species with PL off the scutum and use for the others the generic name of *Euschöngastia* Ewing 1938, which was defined on having a 5-7 pronged palpal claw. In the interim the use of *Euschöngastia* was largely confined to species from the New World, whereas Old World species were allocated to *Ascoschöngastia*. However, more recent studies by Michener, Wharton 1948, and others have shown that the use of the furcation of the palpal claw as a generic character is not to be relied upon and have definitely synonymised *Ascoschöngastia* with *Euschöngastia*. This is at present sound, and can only be upset, and the use of *Ascoschöngastia* be adopted for certain species, if it should become established that characters exist in the nymphs or adults which can be correlated with the off-scutal position of PL in the larvae. Such at present is not the case, indeed, no generic differences can be found between the nymphs of *Ascoschöngastia malayensis* and *A. lacunosa* (Gater) with normal PL or of the species of *Euschöngastia* described by Michener from America. The present writer indicated in a footnote (1952, p. 170) that he was in accord with the use of *Euschöngastia* Ewing 1938 in place of *Ascoschöngastia* Ewing 1946, but circumstances at the time did not then permit the change to be made.

The following therefore shows the correct synonymy, of the two genera considered to be valid :

<i>Euschöngastia</i> Ewing 1938	...	...	<i>Ascoschöngastia</i> Ewing 1951
			<i>Pseudoschöngastia</i> Lipovsky 1951
<i>Tecomatlana</i> Hoffmann 1947	...	...	<i>Sauriscus</i> Lawrence 1949
			<i>Trisetica</i> Traub and Evans 1950
			<i>Anomalaspis</i> Brennan 1952

† Opinions differ on this and some of the succeeding points, and alternative interpretations are discussed in the following paper by Audy, e.g. pp. 125 & 149.—Ed.

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MALAYSIAN PARASITES IX
NOTES ON THE TAXONOMY OF TROMBICULID MITES
WITH DESCRIPTION OF A NEW SUBGENUS

By
J. R. AUDY

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The most comprehensive accounts of the taxonomy of the trombiculids are the excellent and timely monographs published during 1952 by Womersley, by Wharton & Fuller, and by Fuller. Wharton, aided by Fuller, has published an invaluable manual, the taxonomic part of which had however to be completed immediately before a spate of new species were described and without access to Womersley's simultaneous studies of the postlarval stages. Womersley, in a taxonomic compendium, has described and redescribed some 230 species from the Asiatic-Pacific area. He has also made an outstanding contribution to the study of the postlarval stages of trombiculids from the world, but this is a pioneer work and the study of this subject is still relatively undeveloped: only 56 out of some 520 species of larvae have been correlated with the nymphs or adults. Fuller has made a meticulous study of type material in Holland and has added opinions gained from his considerable experience. A number of other workers—such as those involved in the Kansas Chigger Project—are engaged in intensive work on trombiculids and they will certainly be making considerable taxonomic contributions.

A large amount of material from Malaya—over 30 new species with 20 nymphs—has been studied but not described, and unpublished bionomic data have accumulated. In addition, over 15 undescribed species and 13 undescribed nymphs have been collected in North Borneo (by joint research teams in collaboration with Traub and with the financial support of the Surgeon-General's Office, Washington, U.S.A.), and in Sarawak (in collaboration with Tom Harrisson of the Sarawak Museum). It is very unfortunate that some of the more important material came to light too late to be made available to the above authors. It will be several years before the new material can even be described. Although discussion of much of the superficially studied material is premature, the writer believes that at this stage a useful and worth-while appendix can be given to the three monographs already published, so that workers may draw upon some of the Malaysian material in interpreting them and perhaps in dealing with their own taxonomic problems. The writer is aware that he is laying himself open to heavy criticism for some of the prematurely published opinions; nevertheless, the sound council of withholding opinions until they mature may be better for one's reputation but in this particular case it would not be helpful. The taxonomy of the trombiculids is still unsettled even at subfamilial and generic levels, and it must be made clear that the object of this paper is to offer data and a few tentative opinions based on the Malaysian material so that fellow-workers can use them as they see fit in clarifying the taxonomy of these mites. It offers four things: comments on the taxonomic significance of certain characters; some bionomic information of taxonomic interest; provisional revised definitions of genera and subgenera given in the light of the material studied in Malaya over the last five years; and lists of Old World species more or less up to date (early 1953). In order to make the publication more compact and the text easier to scan, authors have been omitted except where there might be confusion, and the trivial names are freely used without their generic initial; the species concerned are those listed by Wharton & Fuller followed by Womersley (who added many new species).

THE TAXONOMIC IMPORTANCE OF VARIOUS CHARACTERS

The various genera and subgenera have apparently been raised in three different ways. Firstly, a genus may be raised on a useful key-character, by which we mean characters, such as the presence of teeth on chelicers, which are convenient for the construction of artificial keys; but these genera have a habit of becoming more and more painfully artificial and sometimes also of accumulating species which are not congeneric—this most commonly happens because it is difficult for the taxonomist not to come to look upon specimens as chitinous patterns on slides, rather than as living creatures. An example is the genus *Schöngastia* (p. 150).

Secondly, a monotypic genus may be raised to accommodate a species with outstanding characters. If it does not remain monotypic, then it is often found that the genotype is not

typical of the whole congeneric group, having in fact drawn attention to itself by some excessively developed character or other. The genus *Doloisia* (p. 157) and subgenus *Trombiculindus* (p. 141) are examples. It has often happened in the Trombiculidae that the characters chosen for generic separation are recurrent polyphyletic characters, which appear independently in various unrelated groups. Such characters and their significance are discussed below. In the case of such genera raised on outstanding characters or groups of characters, it may later be found that a series of the other species puts the genotype in its proper perspective and the genus may then be identified through that series with some other genus, or it may appear to be at the most of no more than subgeneric rank. The selection of some exceptional species as the type of a new genus may give rise to a long delay before genuinely congeneric species are accommodated: the result in any case is frequently a genus of which the genotype is actually not typical of the natural group. This may not be very important, but the delay in recognising the congeneric species may be important and it is simply necessary to bear this in mind constantly. It follows, therefore, that monotypic genera should be raised cautiously and for exceptionally good reasons, especially in the earlier stages of classification.

The third way in which a genus or subgenus comes to be recognised is as a distinct species-group which is in time considered to have a higher status. An example is the *tsutsugamushi*-group of Nagayo and his colleagues. This group was recognised early because a number of similar species were found together in Japan, and the genus *Leptotrombidium* was proposed to accommodate them. This genus is temporarily considered as a subgenus of *Trombicula* sensu lato. Brennan (1952) has drawn attention to the *T. cynos* group as a potential genus. In the case of such genera, a good representative genotype can be selected from the group. This is important because the only question one may ask of a new species is whether or not it is congeneric with any known genotype.

A review of the progress of trombiculid taxonomy reveals four important stumbling blocks, viz. (a) incomplete early descriptions, making many comparisons impossible without reference to the genotype itself—this should be remedied by the redescription of type material (*vide* Fuller 1952) and by the publication of detailed and illustrated comparisons with related species at every opportunity. (b) The interpretation of recurrent polyphyletic characters. (c) The delayed study of the postlarval stages and the interpretation of post-larval characters. (d) The inadequate genotype of *Trombicula*—it is proposed in this paper to adopt, as a provisional substitute for the genotype, a species known in both larva and nymph which appears for very good reasons to be very close indeed to it, if not identical. It will thus at least be possible to build up a consistent subgenus. Points (b) and (c) are discussed below.

Interpretation of recurrent polyphyletic characters

A number of characters are now well recognised as being of polyphyletic origin and occurring as the same deviations from the standard in different groups. There should be a tendency to acknowledge and erect subgenera rather than genera when such characters are themselves made the chief points of difference. Care should also be taken to avoid grouping unrelated species because they share such a recurrent character. Furthermore, only a long study of adequate numbers of species may show whether a recurrent character should be considered as of more than specific importance. It may be wise in each case to start by ignoring the recurrent character completely and attempting to discover the relationships of the species concerned on the remaining characters. Audy (1952) has commented on the poor chitinisation and the posterolateral peninsulas of the scutum of *Trombicula dimolinae*: this group might include members in which the occurrence of PL setae off the scutum is no more than a specific character. In a group related to *Doloisia* (p. 157) this same character appears perhaps to be of subgeneric importance. The more important recurrent polyphyletic

characters are listed below together with references to pages where they are discussed or illustrated.

1. *Variation in the extension of the scutum* to exclude or include setae.—A reduction of the scutum, leaving the PL setae isolated, is encountered in *Tecomatlana*, *Trisetica*, and *Sauriscus* (of which *Sauriscus* at least, and perhaps *Trisetica*, may not be congeneric with *Tecomatlana*; p. 149). *Anomalaspis*; *Speleocola*(?); *Ascoschöngastia* (p. 155), *Pseudoschöngastia* (p. 155); *Apolonia*, *Womersia* (p. 165). This character is discussed by Womersley (1953, this *Study* p. 120). Extension of the scutum to include some of the dorsal setae is especially developed in the Gahrlepiinae (Walchiinae), but it is also encountered in the following, either with inclusion of dorsal setae or reduplication of the PLs: *Novotrombicula* (p. 149), *Heaslipia* (p. 149), and *Mackerrasiella* Wom. 1953: (p. 114)

2. *Scutal submergence and cuticular encroachment*.—A number of unrelated species show some encroachment of the cuticle onto the scutum, or even a partial submergence of the scutum, e.g. *Eusch. rectangulare* (Womersley 1952:186), *T. dimolinae* Audy 1952:139, and *Speleocola tardaridae* Lipovsky 1952:132. The submergence of the scutum is more complete and regular, and in several species apparently of a different nature, in the heterogeneous genus *Neoschöngastia*, and this requires further investigation (see comments, pp. 133, 156).

3. *Division of the femora of legs II and III*.—This has been accepted by many authorities as the chief character which distinguishes the Gahrlepiinae from the Trombiculinae. The division of the femur is a false articulation, sometimes evident only on the ventral aspect of the femur, and in some species (*Pseudoschöngastia*) the division may be difficult to detect in one or other of the legs—although as Brennan (1952) has pointed out, there is no doubt about the division on careful examination.

A species of great taxonomic interest in this connexion is *Schöngastia oudemansi*, the larva of which is distinctive and clearly not congeneric with the other species of *Schöngastia* s. str. (p. 150). It should therefore be taken out and either accommodated in *Euschöngastia* s. lat. or given a new genus or subgenus, the genus or subgenus *Schöngastia* s. str. being redefined accordingly. Fuller (1952) has, we think rightly, placed this species in new genus, *Walchiella*, which however automatically falls in the Gahrlepiinae as at present defined. Both *Walchiella* and the genus *Pseudoschöngastia* have therefore been placed in the Gahrlepiinae by Wharton & Fuller (1952). But the Gahrlepiines form a notably consistent group in both larval and postlarval stages, while *oudemansi* is a typical Trombiculine in all larval and postlarval characters except the division of the femora in the larva. Furthermore, some 21 species, of which 2 are described in this *Study* (p. 84), have now been found which show characters intimately relating *oudemansi* to similar forms without cheliceral teeth but with divided femora, and to others with undivided femora, including *E. lacunosa* (Gater). The nymphs of 4 of these forms are available and they share so many characters with the Trombiculinae and differ on so many diagnostic points from the twelve described gahrlepiinae nymphs, that the affinities of the *oudemansi*-group would appear to lie with the Trombiculinae and near to the *lacunosa*-group. For this reason, we here treat *Walchiella* as a subgenus of *Euschöngastia*, probably related to the sister *lacunosa*-group.

The only reason for suspecting that the *oudemansi*-group is intermediate, linking the Trombiculinae with the Gahrlepiinae, lies in the division of the femora, and *oudemansi* in fact fits more uncomfortably into the Gahrlepiinae on general characters than it ever did in the genus *Schöngastia* s. str. from which it has rightly been rescued. The division of the femora appear to have been independently acquired. Once this character in the legs is not given prime subfamilial importance, the genus *Pseudoschöngastia* also can be seen as being more properly trombiculine; but this genus is different from the *oudemansi*-group in general characters

so that it might in fact be found to represent a link with the Gahrlepiinae; nevertheless, it would appear that the proper place for this genus is at present also with the Trombiculinae. It would almost certainly be a mistake to raise a subfamily for these mites, at least at this stage, because it would be based on the division of the femora, a character of uncertain importance which has probably been independently acquired by *Pseudoschöngastia* and the *oudemansi*-group so that there would arise a simultaneous demand for raising a second subfamily, which is certainly premature. Recent studies of the *oudemansi*- and *lacunosa*-groups have thus greatly strengthened the views expressed by Womersley (1952:12).

4. *Modification of setae*.—This is discussed under *Trombiculindus* (p. 141) and *Fonsecia* (p. 148). Foliate expansions of setae are found in *Trombiculindus* (p. 141), the *Eusch. foliata* group (p. 154), and some *Acomatacarus*. Peg-like modifications or basal swelling of the setae may be noted in *Fonsecia* (p. 148), the dorsal setae of *Eusch. causicola*, the coxal seta on *Trombicula consueta*, and in several leeuwenhoekiiines (*Nothotrombicula*; *Audyana*!). The setal bases of body setae are generally well-chitinised and conspicuous in species of *Walchiella* and the *Eusch. lacunosa* group (p. 153), and in the former subgenus they are further developed into platelets [in *E. (W.) heaslipi*, *traubi*]. Such platelets are also encountered caudally in *Neoschöngastia* species (*entomyza*, *owiensis*, *retrocincta*, *yeomansi*), and in a different form in *Guntherana*. Anal plates are present in two species of *Schöngastiella* (*arona*, *birella*) described by Traub & Evans, 1953:95.

The post-larval stages

1. *Diversity of larval/post-larval stages*.—Most species of trombiculids are known from the larvae, but the number of known nymphs and adults is rapidly multiplying. There appears to be very much less specific and generic variation in the non-parasitic post-larval stages than in the parasitic larval stage. For example, the nymphs of *Heaslipia gateri*, *Trombicula hastata*, and *T. consueta* are difficult to separate and appear to be closely related, but the larvae are very different. Similarly, the nymphs of *Gahrlepieia ornata* and *Walchia lewthwaitei* are closely alike. This may to some extent be because a number of taxonomic characters of importance in nymphs and adults still remain to be recognised. On the other hand there is evidence that there may sometimes be more obvious differences between nymphs than exists between the corresponding larvae, an example from Malaya being the confusion of *T. rara* with another species (to be described) from pill-millipedes until differences in the nymphs led to a re-examination of the larvae (corrigendum on p. 427 of Womersley 1952 refers). At least two other examples have been found (Womersley in correspondence), but the best published examples are those of American species of *Blankaartia* (= *Megatrombicula* Michener) and of *Trombicula autumnalis* in England. Michener (1946), in discussing *T. (Blankaartia) attenuata*, *alleei*, and *velascoi*, of which "not every larva can be definitely placed in one species or another," observed that the corresponding adult characters were conspicuously different. Richards (1950) described considerable variation (five forms) in larvae which were all considered to be *T. autumnalis*. Nymphs were reared only from one form of larva and they showed no particular variations. Womersley (1952:354, 365) considers that Richards was dealing with at least two species, *T. autumnalis* and *T. inopinatum*; but there were nevertheless 5 main forms. However, Jones (1952) has described two easily distinguished forms of nymph bred from a single form of larva of *autumnalis*.

It is of course well recognised, e.g., in the Diptera Culicidae, that rigid ideas on the employment of either larval or adult characteristics are to be deplored. Certainly, species and subgenera based entirely on morphological larval characters may be fully acceptable though the free extension of this to genera (and even to subfamilies, as has been done) is debatable in particular instances. The Culicidae offer a number of examples of specific differentiation in

one stage of the life-cycle but differently, or hardly at all, in the other: in an example from the *Anopheles umbrosus* group, Reid (1950:315) has remarked that it "looks as if the evolution of larval and adult characters in some of these species has proceeded independently along somewhat divergent lines." This is to be expected when the larval and post-larval stages lead such very different lives. Adaptive and other modifications involving the larvae cannot be expected to be reflected by corresponding modifications in the post-larval stages, and *vice versa*. Our main interest in trombiculid mites at present is in their behaviour as parasitic larvae, and it would probably be rational to give more weight to a larval system of classification whenever this is seriously at variance with a post-larval system. Compromises may readily lead to serious difficulties. There is no doubt that taxonomic revisions of the trombiculids should be made very cautiously and not be based on local studies, at this stage, however meticulous these may be.

2. *Standard measurements of Nymphs/Adults*.—The use of the following measurements in the descriptions of nymphs and adults has been agreed upon jointly by Dr. Douglas Gould and the present writer, based on the work done by Jenkins (1949), Wharton *et al.* (1951), Womersley (1952, and various papers), and Wharton & Fuller (1952). The measurements and their abbreviations are offered provisionally pending the publication of joint papers in the next *Study* in this series. The suggestions made below will doubtless be elaborated during the completion of these papers. In describing nymphs and adults the worker confronted by a badly mounted or faded specimen must be borne constantly in mind. Points from which measurements are made should be clearly discernible (e.g., the exact ends of the crista cannot be accurately decided especially in old specimens, hence its length will vary greatly when measured by different workers). Ratios are generally of much greater value than arrays of measurements. A method of graphic or tabular presentation (as with Standard Measurements of larvae) is being devised, and the abbreviations are proposed with this in mind.

Suggested Standard Measurements (Fig. 1)—

Body : Length and Width of propodosoma.

Gnathosome: Lengths of femoral and tibial setae

Lengths of Claw and Tibia (ratio claw/tibia)

Length of cheliceral blade

?Relative proportions of palpal segments.

Scutum: Cristo-pectal length (CTL) from where crista expands into saddle to first median tectal setal base.

ASL—anterior scutal length

SB—sensillary bases

Ratio ASL/SB

C—crista

K—length of carina, when present

PSL—posterior scutal distance

PAD—posterior apodeme

E/ED—diameter of eye/interocular distance

TS—tectal (epistomal) seta(e)

SS—parascutal setae

SENS—sensilla

Legs: proportional lengths entire legs when possible

Length/Height, Tarsus I (and L/Width, as height may not be measurable in many)

Lengths, Tarsus I/Tibia I

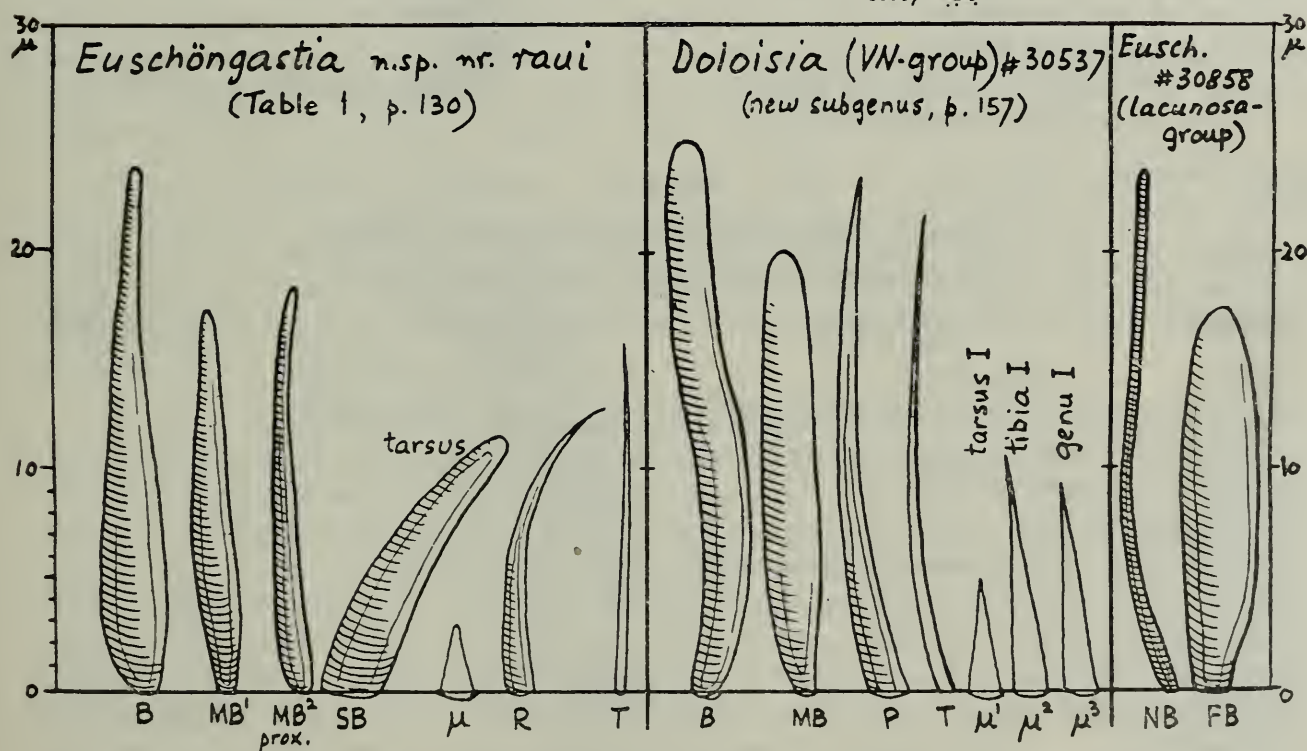
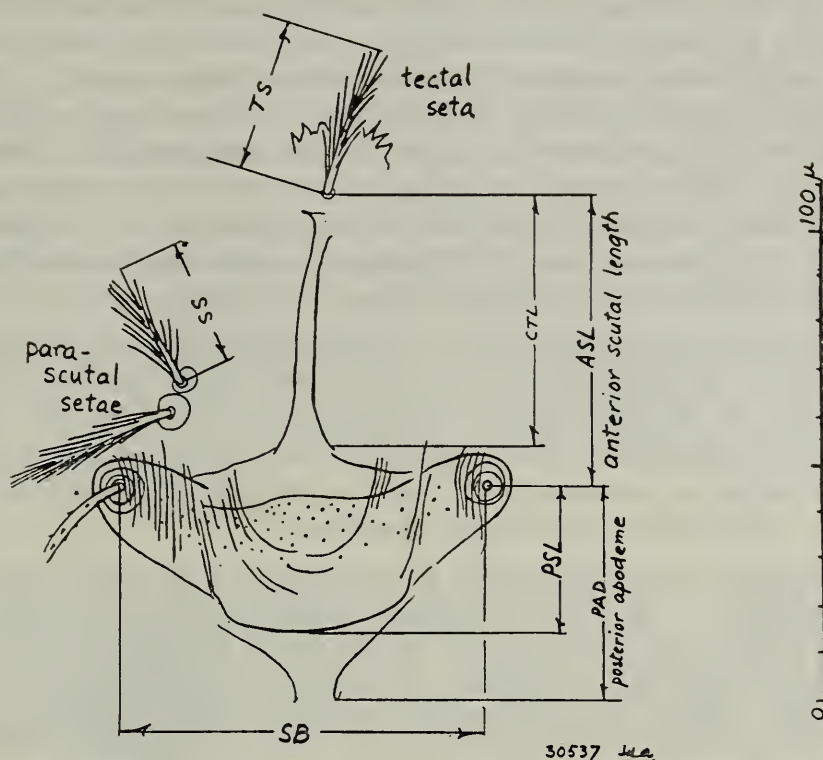
Lengths, Tarsus II/Tibia II

Genitalia: ?Ratio of axial lengths anterior and posterior suckers in nymphs

Ratio of axial lengths genitalia to anus.

Body Setae: lengths and wherever possible ratios of lengths of anterior dorsal setae, posterior dorsal setae, and ventral setae.

3. *Chaetotaxy of legs, Nymphs/Adults*.—The leg setae have been almost completely ignored because they rapidly become difficult to study in old mounts and because they occur in dense setal forests which would deter the most enthusiastic worker. It is however necessary to explore these setae for their possible taxonomic importance, and the present writer has found that the forests of setae can be reduced to some sort of order without undue effort.



I. Scutal measurements and leg chaetotaxy of Nymphs and Adults.

The scutum, of a Nymph of *Doloisia* (VN-group, new subgenus) sp. "VN", shows the more important new measurements and their abbreviations, as listed on page 128.

The sensory setae only (omitting the ordinary barbed or plumose setae which should in practice be drawn with the others) are shown for the legs of the nymphs of *Euschöngastia* sp. nr. *raui* and *Doloisia* (VN-group) sp. "VN"; and in addition, two of the setae (NB, narrow; and FB, flask-shaped) from the nymph of an undescribed species in the *E. lacunosa* group.

Note: This and the following illustrations (pp. 139, 158), with the exception of fig. 3D, are experimental, being reproduced from pencil sketches on thin typing paper, converted to black-and-white line drawings photographically by a technique which is being described elsewhere.

The major types of seta are first picked out, measured, and sketched as shown in Fig. 1. These setae are generally of the following types: (a) Ordinary barbed or pectinate setae (the others presumably being specialised sensory setae of various sorts). (b) Blunt striated setae ("B"), which are typical solenidia and similar to the tarsal spurs of the larvae. (c) Pointed striated setae ("P"), similar to the pointed tibialae and genualae of larvae, and obviously of the same type as the blunt setae. (d) Tapering setae ("T"), slender and usually obviously distinct from the pointed solenidia; these setae appear not to be striated but this requires closer study. (e) Recurved setae ("R"), relatively short, sharp-pointed, and recurved towards the proximal part of the leg; apparently striated. (f) Microsetae ("μ").

One or more distinct representatives of each of these types may be found in a given species, and may be given designations, e.g., LB, MB, FB for long, medium-length, and thick flask-shaped solenidia, or BN for a narrow cylindrical one. The species of nymphs which have so far been examined usually have 6 to 10 distinct setae. As we have already noted, it is important that these be sought out, measured, sketched to scale, and given some sort of letter-designation at the outset. This takes a surprisingly short time.

The next stage is the enumeration and tabulation of the setae, type by type and segment by segment (Table I). It needs very little practice for this to be done quickly. Individual workers will prefer their own systems, but the writer has now come to prefer tabulating the pointed (P, R, μ), blunt (B), and tapering (T) setae in three columns, using the following small letters to suggest roughly the main distribution of the setae on the segment concerned:

d, dorsal aspect.	p, proximal.
v, ventral aspect.	s, distal.
l, lateral (or posterior) aspect.	t, terminal, e.g., near tarsal claw.
m, medial (or anterior) aspect.	

TABLE I.

Example of tabulation of setae on legs of a nymph,
Euschöngastia species in MS, *raui*-group (Fig. 1).

Segment.	Pointed strong setae (P).	Blunt fingerlike setae (B).	Fine tapering setae (T).
Tarsus I	μ (mid-dorsal) ... 11 t (4tm, 4tl in vertical rows)...	10 (8d, m.l.) ... 9M (8s, lp, more slender proximally) ...	—
Tibia I	6oRv (approx. in 9 rows) ... μtl. 2Rt (d.m) ...	2-3S (l.lv) ... 22 (distal 2/3, dt) ...	—
Genu I...	μst ...	3 (2l, tm) ...	16 (prox 2/3; 6d)
Telofemur I	t ...	—	20s
Tarsus II	RtI (terminala) μs (prox. to MB)	M(t) S(p) (not thick)...	—
Tibia II	—	SNt ...	1-2 (p.s)
Genu II	—	—	3s (1pd)
Telofemur II	(t)	—	—
Tarsus III	—	M (st; 15μ) ...	s (prox. to MB)
Tibia III	—	MNtm ...	5 (dt, 2d, 2ps)
Genu III	—	—	2d (tandem)
Telofemur III	t	—	—
Tarsus IV	Rtl	M (prox to LT)	2 (p, & t to MB)
Tibia IV	Rt	—	7 (5p in group)
Genu IV	—	—	5 (4s, p)
Telofemur IV	—	—	—

A meticulous study of the leg chaetotaxy is necessary. This would best be made as a comparative study with the Trombidiidae and related prostigmatic mites. The development of the specialised setae from nymphal to adult stages of the Trombiculidae is also of great interest. The excellent studies made by Grandjean (1943, 1947) may be taken as a model.

4. *The structure of the scutum (crista), Nymphs/Adults.*—There appears to be no satisfactory account of the detailed structure of the scutum, and artists drawing these structures have sometimes shown only one plane, so that similar scuta may be given very different appearances by different artists. The artist himself is seriously handicapped by the lack of a comparative study of this structure. The present writer suspects that there are some fundamental differences in the structure of the scuta of certain groups of trombiculids. A comparative study of uncrushed material as well as serial sections is likely to yield some valuable taxonomic clues. The features which will most repay investigation appear to be (a) the structure of the chitinous vault or roof (*areola*) of the *area sensiliger*a, between the sensillary bases, (b) the development and structure of the apodeme beneath the scutum, (c) the shape of the space enclosed by the walls of the apodeme beneath the *area sensiliger*a (this space may extend towards the chitinous column of the *crista*), and (d) the development of the scutal structures from nymph to adult. The eyes, the para-scutal setae, and the tectum with its seta(e) should be studied together with the scutum.

The larval stage*

1. *Standard Measurements.*—A comparison of standard measurements of the scuta can be misleading and the ready separation of different populations of chiggers by statistical analysis of their measurements is a new pitfall for the unwary. Ratios are generally more valuable than linear measurements. Superimposing tracings of scuta, drawn to the same scale, is a useful way of deciding which ratios are likely to help in separating particular species. Ratios between scutal measurements and measurements of other chitinised parts may be particularly valuable. The present writer has been measuring the tarsus-plus-pretarsus for other reasons and would prefer to take scutal/tarsal ratios. Traub has shown that a scutal/coxal ratio (PW: coxa II) is of great value in separating *T. akamushi* from *T. deliensis* (Traub & Audy, 1953: 86).

Jadin & Vercammen-Grandjean (1952) have added to Womersley's standard scutal measurements but the writer has no comment to make on these except to plead that the number of measurements should be cut down to the absolute minimum. Only usage and experience will allow us to decide what the minimum should be. Certain measurements are useful in some groups but not in others; a routine tabulation will therefore encourage either superfluous measurements or unfortunate omissions.

2. *Chaetotaxy.*—Wharton (1948) found that a detailed study of the chaetotaxy of the legs was of assistance in the recognition and classification of trombiculid larvae, and the importance of this finding has been conclusively demonstrated since. Brennan & Wharton (1950) have surveyed the subgenus *Neotrombicula* in North America and have shown that the leg setae are of specific importance and can be used to advantage in constructing keys. More recently, Brennan (1952) has done the same with the four known American members of the *T. cynos* species-group, while Audy (1952) has dealt with a mixed collection of species of *Trombicula* from bats in Malaya. During the course of studies of Malayan material, in which comparisons have been made with the observations of Wharton and of Brennan, some ideas have emerged concerning the importance of various details, and these are noted below.

* Since this paper went to press, P. H. Vercammen-Grandjean, of the Laboratoire Medical, Province of Kivu, Bukavu, Belgian Congo, has made a most useful observation of a taxonomic character which has hitherto escaped attention, namely, the nature of the internal annular chitinous thickenings of tarsi I in the larvae. These may be partially or fully developed, and there may be one (proximal) or two (proximal and distal). A detailed assessment of this character is being made the subject of a joint paper by Vercammen-Grandjean and Audy, but we may here note that the second distal thickening appears to be regularly present in the Gahrlepiines, in the species of *Walchiella* and the *lacunosa*-group so far examined; while it is poorly developed in some members of the *indica*-group. It is present in a few members of the subgenus *Trombicula*, and is clearly shown in Lipovsky's drawings of *Speleocola*. It is however absent in most chiggers.

The sensory rods (solenidia) of tarsi I and II have been named spurs by Wharton, but Womersley has objected to this use of a term which has special meaning in entomology. Furthermore, the stout blunt character which distinguishes the tarsal spurs may also be shared by the distal tibiala. It is suggested therefore that the sensory rods of the tarsi may be called tarsalae, and the microspurs microtarsalae, thus bringing the nomenclature into line with that of the corresponding setae on the other segments.

Some species or groups tend to have heavily barbed leg-setae, among which nude setae are particularly significant. Other species or groups, e.g. the *indica*-group (p. 154), have leg-setae on which barbs are generally poorly developed: the presence of nude setae among these is usually of much less significance, and these setae should not be freely compared with similar nude setae in other groups. The presence of ordinary leg-setae of different lengths, i.e. long setae and short setae, is however of taxonomic importance, not only at the subgeneric level (as with *Neotrombicula*, p. 143) but at the specific level (the long nude or almost nude setae of *Eusch. audyi*, for example). A third point about these ordinary leg setae also concerns all the setae of the body and palps, and that is that there is no full agreement among acarologists on the proper description of the various types of barbs or other processes which clothe these setae. Descriptions such as *branched*, *barbed*, *plumose*, *ciliated*, *pectinate*, *trifid*, are not used with the same meanings by different workers. The exact description of the setae on body, palps, and legs is however of considerable taxonomic importance and it is proposed in a later paper to illustrate and describe terms which have been agreed upon by those taxonomists concerned.

Apart from inter-specific differences, various combinations of characters, especially in the setation of leg III, have distinct subgeneric and even generic importance. The lengths of the tarsi (including the pretarsus and the bases of the claws so that measurements can be made accurately) and of the sensory rods (tarsalae, spurs) on the tarsi are being recorded for the Malaysian material for later assessment but it is not yet known if this is worth while. The following characters are recorded roughly in the order of what appears to be their importance.

All legs: lengths in relation to thickness (as it is both tedious and inaccurate to attempt to measure legs which are considerably bent, the tarsi might perhaps be taken to represent the legs); plumosity or nudity, and relative lengths, of the leg setae generally; occasionally, claws and empodium deserve comment.

Leg III: all specialised setae, especially the whip-like setae. The latter appear to be of two distinct kinds: true solenidia, like the femoralae and genualae, which are unusually long and whip-like, generally curved, showing the hollow refractile appearance and often the striae of the shorter setae; and long nude setae which resemble the ordinary non-specialised setae. The latter are usually straight and outstanding, so that the description whip-like is not very apt; similar setae may carry traces of ciliations or barbs near the base, others may carry a few barbs but have a long free tip (cf. *T. flagellifera*, *tuhana*). The terms mastitarsala, mastitibiala, etc. are retained for the latter type of seta, while the former type is described as whip-like tibialae, genualae, etc. (Audy, 1952): Wharton, in correspondence, states that this is the correct usage of his terms, while he also refers to the short (not whip-like) nude setae as, e.g., "a short mastitibiala".

Leg I: The position of the microtarsala in relation to the base of the tarsala; the general shape and size of the sensory setae (these may be short, stout, slender, long, pointed or blunt; the distal tibiala on leg I or II may be blunt while the proximal seta is pointed and more slender). The relative lengths of the microsetae (the microtibiala and microgenuala may at times be very long); in addition, the microsetae may occasionally be modified, as in the hook-like microtarsala of *T. harrisoni*. Occasionally the presence of long nude, plumose, or pectinate setae, sometimes mastisetae, on the femur; occasionally, the length of the parasubterminala relative to the subterminala.

Leg II: position of microtarsala relative to base of tarsala; whether the tibialae are in tandem or not.

In general, an attempt has been made in all descriptions to refer measurements to comparisons with other features which will be before the observer on the same part of the specimen, so that setae may be compared with the lengths of segments, or, for example, the microsetae or parasubterminala with their associated sensory setae. In illustrating the leg setae, it is probably best to concentrate effort on the shapes and positions of the sensory setae, and to show only the bases of the other setae together with a few examples to illustrate the type

of branching. It is necessary to show at least all the bases of setae in order to help the worker confronted with a specimen in which setae may be missing.

Certain features are so regularly present that nothing whatever is gained by their enumeration in every description. The five special setae on tarsus I are an example. Only the rare deviation from this need be noted, as in the case of the multiple spurs in *Phrynacarus*.

Regarding the body setae, Audy (1952:153) has appealed for a standardisation in the description of the dorsal (DS), caudal or postanal (CS) and ventral (VS) setae. The following is an example of a standard description suggested by him: "*Body setae*: DS fairly slender, similar to PL scutal setae, with short barbs, arranged in rows but with irregular setae medially and laterally in the first row and laterally in other rows, e.g., 2.4.10.4.12.6.6.4, totalling 44-60 DS (42 to 32 μ ; humeral setae 45 μ) + caudal setae (CS) in rows on level of and behind anus, 14-16 CS (total setae of dorsal type 64-74) + 22-26 VS (27 μ) more slender, with two or three lateral barbs and a free pointed tip, arranged roughly in rows and more or less distinct from the caudal setae. One pair of sternal setae between coxae I and two pairs of sternal setae between coxae III." Reasons for attention to these differences are given under the genus *Fonsecia* below (p. 148).

3. *Convergence in larval characters*.—The very close resemblance between *Trombicula munda* and *Euschöngastia indica*, mentioned on p. 154, is one example of a troublesome problem for the taxonomist. The occurrence of *T. munda* on particular hosts in company with large numbers of *E. indica* and *E. audyi*, e.g. on *Rattus r. diardii* in houses, may be interpreted by assuming that its life-cycle is passed mostly in or near the nests of its hosts. The resemblance between *munda* and *indica* would appear to be due to a convergence of characters, and in this particular instance this convergence might possibly be associated with the similar habitats which the two species appear to share. The present writer is reluctant to assume that there need be any particular taxonomic relationship between these two species in spite of the morphological evidence. It is obvious that the nymph of *munda* is of exceptional taxonomic interest, but efforts to obtain it have so far failed because this is an uncommon species.

Another example of convergence is to be found in *T. beltrani* Hoffman (from a bat in Mexico), of which the scutum, the curved claws, and the peculiar small angulated (but not toothed) chelicers, give the larva a curiously close resemblance to members of *Doloiisia* sensu lato, from ground-mammals in Malaysia and Africa. Both these examples of convergence are incidentally between the *indica*- and *Doloiisia*-groups, which have many features in common (p. 154), and what we take to be the subgenus *Trombicula*.

When the genus *Neoschöngastia* (see p. 155) is studied intensively it will be necessary to consider to what extent the characteristic submergence of the scutum is or is not a polyphyletic character, associated perhaps with the avian habitats, possibly resulting in a convergence of characters in larvae which should in fact be accommodated in several genera.

4. *Complexes of "seasonal" forms*.—The presence in the same country of a number of closely related species which differ not only morphologically but in having different seasonal incidences is extremely interesting. Examples are species of *Leptotrombidium* in Japan (Nagayo *et al.* 1927), of *Neotrombicula* in North America (Brennan and Wharton, 1950) and the forms of *T. (Neotrombicula) autumnalis* in Britain (Richards, 1949). There is a possibility here of a form of ecological subspeciation which is worth investigation.

For example, the species of *Leptotrombidium* (*akamushi*-group) studied by Nagayo *et al.* in north-west Honshu, Japan, showed different seasonal incidences. *T. akamushi* was the dominant species in mid-summer (a single peak of 21 mites per vole was recorded for August, 1919, dropping to a negligible number in October). *T. intermedia* appeared for only three

months with a peak in October. *T. pallida* showed one peak in May-June and another in September-October (which might suggest that this is a cold-weather species with a 3-4 month summer cycle which is extended over some 8 months through the winter). *T. palpalis* resembled *T. pallida* in having two peaks but it appears to be a true winter species with a peak in November followed by a second between January and April, the summer trough being very low. A fifth species, *T. scutellaris*, was not studied by these authors, but it appears to have a single peak roughly coinciding with that of *T. intermedia*.

The five members of the *T. akamushi* group thus show different patterns of larval incidence, *T. akamushi* alone dominating the mid-summer. An important point is that though all these mites may infest the same hosts, this seasonal behaviour tends to isolate the populations of the different species by the phase-dislocation of their various activities. An interesting speculation presents itself. The overall climate in a country is broken up by features such as aspect, exposure, drainage, and local cloud-formation into a mosaic of local climates—so that for example, spring and autumn do not develop exactly in step on the north and south slopes of a mountain nor does a prevailing condition produce the same effect in a valley as it does on an exposed slope. Such local vagaries of climate, coupled with edaphic factors and perhaps phases of behaviour of the hosts, may therefore conceivably tend to set several populations of the same species out of step with each other in their life-cycle rhythms, in which case a degree of isolation of the populations should tend to develop. The original "seasonal" species may thus in effect be broken up into a number of isolated populations exposed to different selective influences. The writer is not in a position to suggest that something of this sort may explain the presence of some of the forms of *Leptotrombidium* in Japan or of *Neotrombicula* in America and Britain, but such a possibility should be borne in mind when considering the peculiarities of speciation in closely similar forms with seasonal individuality.

PROVISIONAL DEFINITION OF TAXONOMIC UNITS OF OLD-WORLD CHIGGERS

The following list shows the families, subfamilies, genera, and subgenera as accepted by Womersley (1952), and Wharton and Fuller (1952), and as tentatively accepted in the present paper:

SUBFAMILIES, GENERA, AND SUBGENERA

Abbreviations:	<i>n, a.</i> :	nymphs, adults known
	<i>N, A.</i> :	known only from nymphs, adults (larvae unknown)
	<i>OW.</i> :	genus/subgenus known only from Old World
	<i>NW.</i> :	genus/subgenus known only from New World
	*	genus/subgenus described since the publication concerned

Present paper.	Wharton and Fuller, 1952.	Womersley, 1952.
TROMBICULIDAE ?s. s.	TROMBICULIDAE s.l.	TROMBICULIDAE s.s.
TROMBICULINAE	TROMBICULINAE	TROMBICULINAE
Group A:		
<i>Trombicula</i>	<i>Trombicula</i>	<i>Trombicula</i>
(<i>Trombicula</i> s.s.) ?OW. n.a. ...	(<i>Trombicula</i> s.l.+) ...	(<i>Trombicula</i> s.s., partim)
(<i>Eutrombicula</i> s.s.) n.a. ...	(<i>Eutrombicula</i>) ...	(<i>Trombicula</i> , partim)
(<i>Leptotrombidium</i> s.l.) n.a. ...	(<i>Leptotrombidium</i> s.s.) ...	(<i>Leptotrombidium</i> s.l.)
(<i>Trombiculindus</i> s.l.) OW. n. ...	(<i>Trombiculindus</i> s.s.) ...	(<i>Trombiculindus</i> s.s.)
(<i>Crotiscella</i>) NW. ...	(<i>Crotiscella</i>) ...	(<i>Crotiscus</i>)
(<i>Neotrombicula</i> s.s.) n.a. ...	(<i>Neotrombicula</i> s.s.) ...	(<i>Neotrombicula</i> s.l.+)
(<i>Blankaartia</i> s.s.) n.a. ...	(<i>Blankaartia</i> s.s.) ...	<i>Tragardhula</i> (<i>Blankaartia</i> s.l.)
<i>Fonsecia</i>	(<i>Fonsecia</i>) ...	<i>Trombicula</i> (<i>Fonsecia</i>)
<i>Tecomatlana</i>	<i>Tecomatlana</i> ...	<i>Tecomatlana</i>
(<i>Tecomatlana</i>) NW. ...	= <i>Sauriscus</i> = <i>Trisetica</i>	= <i>Sauriscus</i> = <i>Trisetica</i>
(<i>Sauriscus</i>) OW.		
(<i>Trisetica</i>) OW.		

<i>Speleocola</i> NW. n.	...	...	*	...	...	*
<i>Anomalaspis</i> NW.	...	...	*	...	...	*
<i>Myotrombicula</i> OW.	...	...	<i>Myotrombicula</i>	...	...	<i>Myotrombicula</i>
<i>Heaslipia</i> OW. n.	...	...	<i>Heaslipia</i>	...	...	<i>Heaslipia</i>
<i>Novotrombicula</i> OW.	...	...	<i>Novotrombicula</i>	...	...	<i>Novotrombicula</i>
<i>Ipotrombicula</i> OW. A	...	...	*	...	...	<i>Ipotrombicula</i>
<i>Speotrombicula</i> NW. A.	...	...	<i>Speotrombicula</i>	...	...	<i>Speotrombicula</i>
Group B:						
<i>Oenoschöngastia</i> OW.	...	...	<i>Oenoschöngastia</i>	...	...	<i>Oenoschöngastia</i>
<i>Radfordiana</i> OW.	...	...	*	...	...	<i>Radfordiana</i>
—	—	—	—	—	—	<i>Schöngastia</i> s.l.
<i>Schöngastia</i> s.s. OW. n.a.	...	...	<i>Schöngastia</i>	...	...	(<i>Schöngastia</i>)
<i>Euschöngastia</i> s.l.	...	...	<i>Euschöngastia</i> s.l.	...	...	(<i>Eusch.</i> = <i>Ascosch.</i> s.l.)
(<i>Euschöngastia</i> s.s.) NW.	...	...	—	...	...	—
(<i>Helenicula</i> nov.) OW. n.	...	...	—	...	...	—
(<i>Walchiella</i>) OW. n.a.	...	...	<i>Walchiella</i> in WALCHIINAE	...	...	(<i>Schöngastia</i>)
(?n. subg. <i>lacunosa</i> -group) OW. n.	...	...	<i>Euschöngastia</i>	...	...	(<i>Eusch.</i>)
(?n. subg. <i>indica</i> -group) OW. n.a.	...	...	<i>Euschöngastia</i>	...	...	—
<i>Ascoschöngastia</i> s.s. n.	...	...	<i>Ascoschöngastia</i> s.s.	...	...	—
<i>Pseudoschöngastia</i> NW.	...	...	<i>Pseudoschöngastia</i> in WALCHIINAE	...	...	—
<i>Neoschöngastia</i> n.	...	...	<i>Neoschöngastia</i>	...	...	<i>Neoschöngastia</i>
<i>Mackiena</i> OW.	...	...	<i>Mackiena</i>	...	...	<i>Mackiena</i>
<i>Guntherana</i> OW. ?a.	...	...	<i>Guntherana</i>	...	...	<i>Guntherana</i>
<i>Doloisia</i> s.l.	...	...	<i>Doloisia</i> s.s.	...	...	<i>Sch.</i> (<i>Eusch.</i>)
(<i>Doloisia</i> s.s.) ...	...	...	*	...	...	*
(n. subg. in MS) OW. n.	...	...	...	...	...	...
(?n. subg. <i>oculicola-crocidura</i> group) OW. n.	...	...	<i>Euschöngastia</i>	...	...	<i>Sch.</i> (<i>Eusch.</i>)
<i>Riedlinia</i> OW.	...	...	<i>Riedlinia</i>	...	...	<i>Riedlinia</i>
<i>Endotrombicula</i> ...	...	...	<i>Endotrombicula</i>	...	...	<i>Endotrombicula</i>
(<i>Endotrombicula</i>) NW.	...	...	(<i>Endotrombicula</i>)	...	...	(<i>Endotrombicula</i>)
(<i>Phrynacarus</i>) OW.	...	...	(<i>Phrynacarus</i>)	...	...	(<i>Phrynacarus</i>)
GAHRLIEPIINAE pro tem.			WALCHIINAE.		GAHRLIEPIINAE.	
<i>Gahrlepie</i> s.l.	...	...	—	...	...	<i>Gahrlepie</i> s.l.
(<i>Gahrlepie</i> s.s.) OW. n.a.	...	...	<i>Gahrlepie</i> s.s.	...	...	(<i>Gahrlepie</i> s.s.)
(? <i>Gateria</i>) OW. n.	...	...	<i>Gateria</i>	...	...	(<i>Gateria</i>)
(? <i>Giroudia</i>) OW. n.	...	...	*	...	...	*
(? <i>Schöngastiella</i>) OW. n.	...	...	<i>Schöngastiella</i>	...	...	(<i>Schöngastiella</i>)
(? <i>Walchia</i>) n.a.	...	...	<i>Walchia</i>	...	...	(<i>Walchia</i>)
<i>Eusch.</i> (W.) in TROMBICULINAE	...	...	<i>Walchiella</i>	...	...	<i>Sch.</i> (<i>Sch.</i>) in TROMBICULINAE
<i>Pseudosch.</i> in TROMBICULINAE	...	...	<i>Pseudoschöngastia</i>	...	...	<i>Sch.</i> (<i>Eusch.</i>) in TROMBICULINAE
(? LEEUWENHOEKIIDAE)	...	...	not recognised as a Family		LEEUEWENHOEKIIDAE	
LEEUEWENHOEKIINAE			LEEUEWENHOEKIINAE		LEEUEWENHOEKIINAE	
<i>Leeuwenhoekia</i> ...	...	...	<i>Leeuwenhoekia</i>	...	...	—
(<i>Leeuwenhoekia</i>) NW.	...	...	(<i>Leeuwenhoekia</i>)	...	...	—
(<i>Comatacarus</i>) NW.	...	...	(<i>Comatacarus</i>)	...	...	—
<i>Acomatacarus</i> ...	...	...	<i>Acomatacarus</i>	...	...	—
(<i>Acomatacarus</i>) n.a.	...	...	(<i>Acomatacarus</i>)	...	...	—
(<i>Austracarus</i>) OW.	...	...	(<i>Austracarus</i>)	...	...	—
(<i>Austrombicula</i>) OW.	...	...	(<i>Austrombicula</i>)	...	...	—
(<i>Hyracarus</i>) OW.	...	...	(<i>Hyracarus</i>)	...	...	—
(<i>Xenacarus</i>) NW.	...	...	(<i>Xenacarus</i>)	...	...	—
<i>Chatia</i> NW. n.	...	...	<i>Chatia</i>	...	...	—
<i>Shunsennia</i> ...	...	...	*	...	...	—
<i>Hannemania</i> n.a.	...	...	<i>Hannemania</i>	...	...	—
<i>Odontacarus</i> NW.	...	...	<i>Odontacarus</i>	...	...	—
<i>Whartonia</i> n.	...	...	<i>Whartonia</i>	...	...	—

APOLONIINAE s.l.			APOLONIINAE.			APOLONIINAE.		
<i>Apolonia</i> NW.	...	...	<i>Apolonia</i>	...	...	<i>Apolonia</i>		
<i>Sauracarella</i> OW.	...	...	<i>Sauracarella</i>	...	...	<i>Sauracarella</i>		
<i>Womersia</i> NW.	...	...	<i>Womersia</i>	...	...	<i>Womersia</i>		
? <i>Womersleyia</i> OW. n.	...	...	?? a TROMBIDIID			<i>Womersleyia</i>		
? <i>Grossia</i> OW.	...	...	*			<i>Grossia</i>		
? <i>Neotrombidium</i> a.	...	...	?? a TROMBIDIID			? <i>Neotrombidium</i>		
? <i>Nothotrombicula</i> OW.	...	...	?? a TROMBIDIID			<i>Nothotrombicula</i>		
? <i>Cockingsia</i> OW.	...	...	*			<i>Cockingsia</i>		
? <i>Mackerrasiella</i> OW.	...	...	*			<i>Mackerrasiella</i>		

The scheme of classification which follows is essentially provisional. Circumstances have precluded writing this preliminary account in collaboration. It has also been necessary to postpone publication of a paper (Audy, 1955) describing certain species of special taxonomic interest: this paper will be published in the following *Study* of this series, while only the essential references to it will be made here. In drawing up the present scheme, the diagnoses of the taxonomic units are generally those of Womersley and of Wharton & Fuller, with any existing anomalies between them resolved as far as possible, often by compromise. The origin of the diagnoses is acknowledged where necessary, with a note as to whether they are unchanged or have been modified; but the term "amended" is not used here as the writer believes it should be reserved for considered decisions and not provisional amendments. In making decisions as to the generic or subgeneric rank of a number of units the following tenets have been accepted: (a) valid genera and subgenera may be based on larval morphological characters alone; (b) biological features such as host-preferences or peculiar habitat-preferences should be included in the consideration of natural relationships and may guide one in according independent status to groups of species; and (c) special care should be exercised in dealing with recurrent polyphyletic characters. In defining these units, the principle has been adopted that at this stage it is advisable to expand them whenever this leads to a better organisation of the known species into the scheme of classification. In a few cases (e.g., *Schöngastia*) concepts of genera have however been restricted.

The Malaysian material comprises some 130 species of larvae and 73 nymphs, descriptions of a number of which are yet unpublished. This material has been scrutinised to see what light it can throw on the many taxonomic problems, but because a good deal remains to be studied carefully the opinions expressed are only tentative. They are nevertheless likely to be useful to other workers. The writer believes that the greatest need now is for all groups of two or more closely related species to be recognised and listed preparatory to detailed study; for exhaustive descriptions or redescriptions to be made of all genotypes and representatives of species-groups, so that proper standards are set for comparative studies and descriptions; for geographically local exhaustive studies of genera, subgenera, and species-groups to be made and to be followed by world-wide comparative studies; for the postlarval stages to be explored for more characters of taxonomic importance, and for more extensive breeding of these stages to be undertaken. These needs are guiding the work of this research team, particular importance being attached to the *akamushi*-, *wichmanni*-, *indica*-, *lacunosa*-, and *oudemansi*-groups, each of which includes a dominant species in Malaysia (although *T. wichmanni* is not dominant in our particular collections in Selangor, it is dominant elsewhere, and the group is represented in the Americas).

FAMILY TROMBICULIDAE EWING

Diagnosis.—(1) *Sensu stricto* after Womersley (1952:13, *verbatim*): Larvae with only 1 AM seta, or none, on scutum and no antero-median scutal process. Stigmata and tracheae absent (? rarely present). Nymphs and Adults figure-eight shaped, with a distinct medial constriction, and propodosoma not wider than hysterosoma. Crista anteriorly ending in a hyaline dentate epistome (tectum) furnished with a single ciliated seta. Eyes 1+1 or absent, when present either closely adjacent to sensillary area, or away from and in front of this area.

STUD. INST. MED. RES.

(2) *Sensu lato* after Wharton and Fuller (1952:40-41): there is nothing controversial in the broad diagnosis given by these authors, who unlike Womersley recognise only one family of chiggers.

Remarks.—Whether or not one accepts the single broad family or the two families Trombiculidae and Leeuwenhoekiidae, it is important to recognise that there are some relatively poorly studied “leeuwenhoekiid” groups of genera which appear to have a confusing number of affinities with the Trombidiidae. It may therefore help to add the following notes on the family Trombiculidae taken *sensu stricto*, so that comparisons may be made with the Leeuwenhoekiidae of Womersley (p. 163 below) and with the Trombidiidae (p. 166).

Larvae with a dorsal plate (scutum), very rarely with accessory dorsal plates (caudal in *Guntherana*; at bases of dorsal setae in a few species). Scutum posterior to gnathosome (apparently overlapping it only sometimes with extreme engorgement), without anterior median process or nasus (unless one is to include *Hannemania* on account of the constricted adults, see p. 164), usually with 5-6 scutal setae (2, 3 or rarely 4 setae anteriorly) but may be up to 20 (*Gateria* species); always with one pair of sensillae, filiform (rarely nude, usually barbed or plumose) or expanded. Eyes if present usually 2+2, often on a distinct ocular plate. Seta on fused palpal coxa posterior to base of palpal femur, usually with long barbs or branches. Femora of legs usually divided (7 segmented legs), sometimes (and regularly in Gahrlepiines) undivided in legs II and III. All coxae usually 1-setose; coxa I and/or II multisetose in typical *Dolosisia*, otherwise 1-setose; coxa III multisetose in several unrelated groups and frequently in the Gahrlepiines. Sternal setae 2 pairs, rarely 3. Larvae parasitic on vertebrates, very rarely on arthropods.

Nymphs and Adults mostly small (1 mm or less); body constricted (“figure eight”). Scutum with one pair of filamentous sensillae (sometimes spatulate or mid-shaft thickened) arising from a subposterior sensillary area, ending anteriorly in a variously shaped, usually denticulate tectum (epistome) bearing a single seta (2 in *Tr. camilla*; in *Ipotrombicula*, known only from the adult, there is an accessory seta at the base of the crista). Eyes if present single, either close to sensillary area, or lateral to crista and away from scutum; if absent may be represented by pigment spots.

Subfamily TROMBICULINAE Ewing

Diagnosis (slightly modified).—Trombiculids whose larvae have a single median scutal seta (‘AM’), no anterior projection (nasus) on the scutum, and no stigmata or tracheal trunks; femora of legs II and III only occasionally undivided (all legs usually 7-segmented.) Nymphs and Adults without dorsal stump-like process to tarsus; frequently with scutum relatively long compared with breadth.

Remarks.—The writer prefers to distinguish two broad generic groups in this subfamily, related respectively to *Trombicula* (with unexpanded sensillae) and to *Euschöngastia* (with terminally expanded sensillae), the latter group having a greater number of affinities with the Gahrlepiinae (=Walchiinae) in the presence of expanded sensillae, the presence of undivided femora in at least two different groups (*Walchiella* and *Pseudoschöngastia*), the relative frequency of multisetose coxae, and in the shape of the scuta of the nymphs and adults (resembling those of the Gahrlepiines in the genera *Guntherana* and *Dolosisia sens. lat.*).

A. *Trombicula* GROUP OF GENERA—FILIFORM SENSILLAE

Genus *Trombicula* Berlese 1905, expanded

Type.—*Trombicula minor* Berlese, 1905:155, *Redia*, 6, 346-388. Adults from bat-guano, cave in Java (types now destroyed).

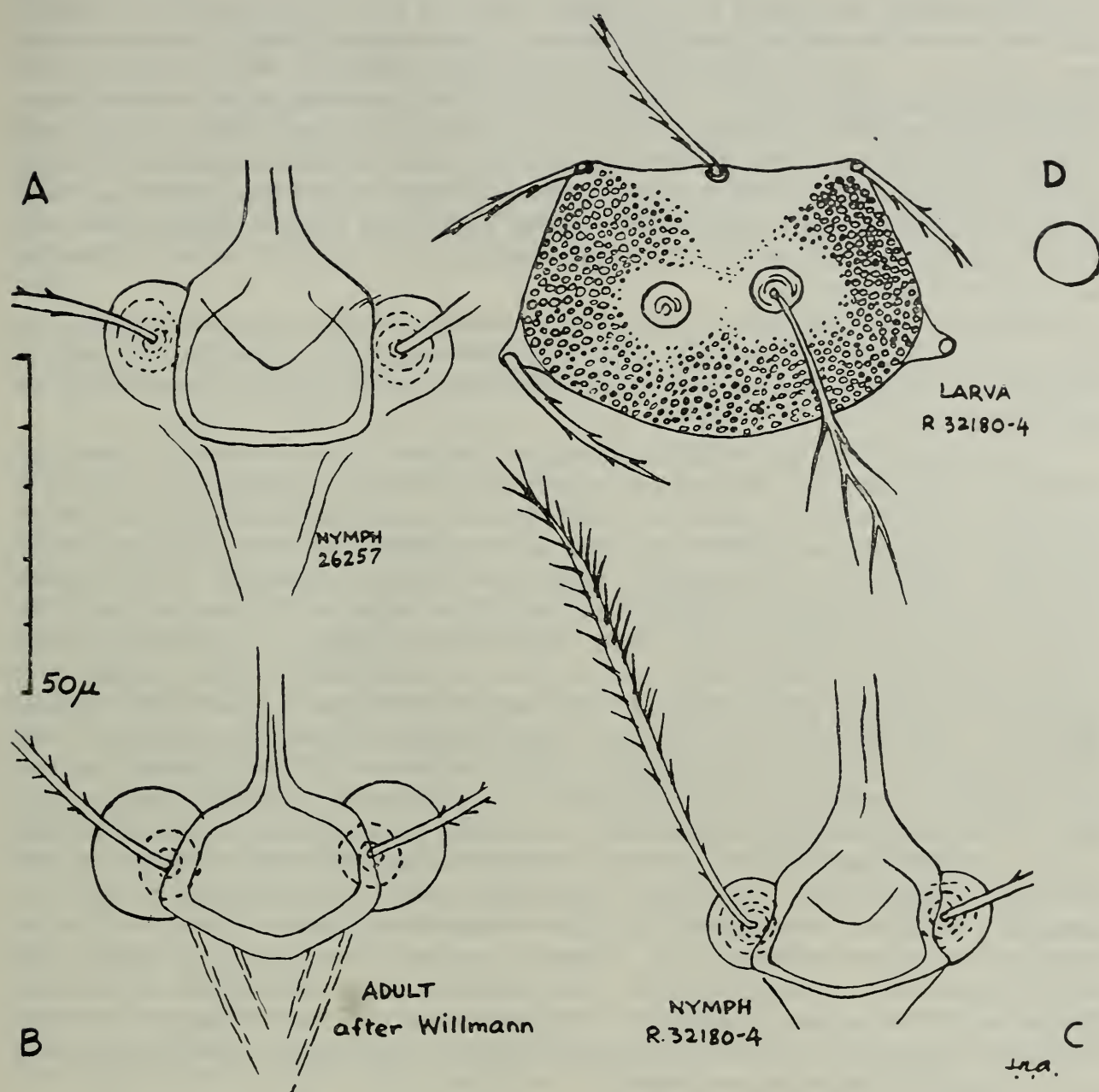
Provisional Diagnosis (tentative broad genus).—Trombiculines whose larvae have 5 scutal setae, unexpanded sensillae (mid-shaft occasionally slightly thickened, e.g. in *harrisoni*-group), only coxa III ever with more than one seta and that exceptionally, tarsal claws normal with slender clawlike empodium. Nymphs and Adults with generally elongate scutum, sensillary area roughly diamond-shaped, with roughly dumb-bell shaped areola; eyes when present either placed close to sensillary bases or lateral to crista and away from the scutum. Sternum entire, precoxal plates generally absent, but in subgenus *Leptotrombidium* precoxal plate of leg I present and fused to form a longitudinally subdivided sternum.

Remarks.—The type species is unknown in the larval stage, while its description in the adult stage is very incomplete. The type specimens, from a bat-cave in a remote part of Java, were destroyed by the bombing of Hamburg during the war. Dr. Cornelius B. Philip in March 1948 approached Dr. A. Diakonoff of the Zoologisch Museum en Laboratorium at Buitenzorg (now the Museum Zoologicum Bogoriensis, Bogor, Indonesia), but attempts to collect some more material in the type locality failed. Dr. Diakonoff has since been appointed to the Rijksmuseum at Leiden. The present writer recently attempted to get more material collected, but in a letter dated June, 1953, Dr. M. A. Lieftinck, Director of the Museum at Bogor, explains that "there are still difficulties in getting to the Tjiampia caves and I fear that there will be no chances of this at all since I have been informed that the bat caves at this locality are entirely spoiled, the fauna having disappeared almost completely. So there is no particular reason to visit the spot again, except for a pilgrimage. Since, as far as I know, there is no one in Indonesia working on Trombiculids at the moment, practically none of the former rich bat cave localities being at all accessible, I am afraid that I should not succeed in getting specimens for you from elsewhere."

Willman (1941) gave a redescription of the type together with drawings of part of the scutum and palps. Unfortunately there was at that time very little material available for comparison, so that the redescription is incomplete in the light of post-war studies. It is also important to note that the drawing of the parts of the scutum which Willman wished to discuss is semi-diagrammatic. Gunther (1951) has given a valuable review of the early descriptions of *minor*, and its later temporary confusion with the scrub-itch chigger *T. wichmanni*.

We know that *T. minor* is a very small species (adult about the size of most nymphs), and that being recovered from bat-guano the larvae are perhaps more likely to be found on bats than other animals; while we have an imperfect drawing of the scutum and palps, and meagre descriptions of features which are not of generic importance. The writer wishes to comment on two problems: the interpretation of the existing drawing and description of the type, and the best way of handling this difficult genus.

Womersley (1952:328) interprets the relatively large circles around the sensillary bases of *T. minor* (fig. 2) as being eyes which have been displaced so as to lie behind the sensillary bases. In this he differs from Ewing (1944) who believes that the circles represent chitinous rings. On this assumption Womersley erected his subgenus *Trombicula* which is in fact based on the post-larval characters of *T. wichmanni* and other species of *Eutrombicula*. The present writer doubts Womersley's interpretation of Berlese's and Willmann's drawings for the following reasons: (a) the bilateral symmetry argues somewhat against distortion and displacement; (b) taking the actual small size of the scutum into account, the "sensillary bases" as drawn are relatively much too small because these structures do not vary greatly in size as does the scutum generally; (c) the overlap between the edges of the sensillary bases and the intervening part of the scutum is taken by Womersley to be evidence of displacement of both sensillary bases and the "eyes" and so also is the eccentric origin of the sensillae themselves; but such a partial overlap may often be seen in specimens where the intervening sensillary area is convex, while even if there is displacement this still does not suggest the existence of eyes; and the eccentric origin of the sensillae is quite commonly seen; (d) the larvae of species which have been associated with *minor* in possessing eyes in the postlarval stages are bird and reptile chiggers (here treated as subgenus *Eutrombicula*) quite unlike any chiggers so far recovered from bats in this region; (e) three species of *Trombicula* now known from bats are very small, but not one resembles *Eutrombicula*; (f) two species of nymphs examined by the writer (fig. 2) show a sufficiently close resemblance to the drawing of *minor* to suggest that the larger circles drawn from type material are the rims of the sensillary bases and not



2. *Trombicula minor* and related species.

A, scutum of Nymph, *Trombicula* sp. (?*T. batui*) found in bat-guano, Malaya ; B, scutum of Adult of *T. minor*, after Willmann ; C, scutum of Nymph, and D, scutum of Larva, species near *T. minor* from bat, Malaya.

The original drawing (B) by Willmann is semi-diagrammatic and refers to an adult ; A & C are drawn somewhat similarly from nymphs for comparison. The inner line extending from the shaft of the crista and expanding into the areola in B shows structure lying deeply, the surface structure being omitted. This is in accord with the inclusion of the posterior apodeme which also lies deeply (see comments on structure of the scutum on p. 130). Note : In D, the PL setae can be seen placed on poorly chitinated extensions. In old mounts the edge of the almost-reticulated scutum is very distinct and only with difficulty, under phase-contrast, can this chigger be distinguished from species of *Tecomatiana*.

eyes. It would therefore appear that Ewing's interpretation of the circles in the original drawings is correct.

The following bat-chiggers are diminutive, similar in size to *Euschöngastia* (*Walchiella*) *oudemansi*, and of the order of size of *T. minor*: *T. minutissimum* (Ouds.) (distinctive larva, from Europe, see p. 147); *T. batui* Philip and Traub (also distinctive); *T. n. sp. R32181* Audy in MS (bred to the nymph, fig. 2). In addition to the last-named nymph, the writer recovered a single small nymph from bat-guano from a cave on Seletan Island. This cave had been occupied by tomb-bats, *Taphozous melanopogon*, from which *Trombicula taphozous*, *T. insolli*, and *T. batui* were recovered: the nymph is likely to belong to one of these species, and from its fairly small size it might even be *batui*. In fig. 2 the scuta of these nymphs have been drawn in outline for comparison with the reproduction of the scutum of *minor*, at about the same degree of enlargement.

The writer concludes that the genotype of *Trombicula* is without eyes in the nymphs and adults and that although assumptions as to close larval relationships cannot yet be made by comparisons of nymphs, the nearest relations so far found are the above new species (*R32181*) and probably *batui*.

Concerning the best way to stabilise this genus, Wharton and Fuller (1952:41) state that "Berlese's description and Willmann's redescription of the type indicate that *T. minor* is congeneric with the adults of larvae that will key to the genus *Trombicula* in the above key." This broad statement is acceptable but it must also be admitted that not enough is yet known of nymphs and adults to be confident of generic or subgeneric differences. The statement therefore does not exclude the possibility that any of the subgenera of *Trombicula* sensu lato may prove not to be congeneric with *minor*. These authors continue "In order to maintain stability in the use of *Trombicula* as a generic name, the subdivisions of this originally large genus are here considered as subgenera. The only other alternative would be to consider *Trombicula* as containing only the genotype until additional information is obtained. Such a course would be entirely unjustified since, despite the plethora of generic names that have been proposed, *Trombicula* as here understood is no broader in its content than are such genera as *Neoschöngastia* and *Euschöngastia*. In handling nomenclatorial problems of this kind stability should be maintained if it at all possible to do so and still remain in agreement with the known biological facts." The present writer agrees with the course suggested but would urge that a number of the subgenera should be recognised as genera whenever they can be clearly and unequivocally distinguished. *Fonsecia* is a case in point (see p. 148 below), while possibly *Eutrombicula* (see p. 145) may also justifiably be separated from *Trombicula*. *Blankaartia* (= *Tragardhula*) is probably a valid genus but until the confusion of larvae of *Blankaartia* with some of those of *Neotrombicula* can be satisfactorily cleared it is probably best to recognise *Blankaartia* as a subgenus.

Wharton and Fuller include in the subgenus *Trombicula* all the species which cannot definitely be grouped in the other subgenera, which they have in each case treated in a restricted sense (e.g., *Leptotrombidium* is practically restricted to the *akamushi*-group). The usefulness of this course is doubtful to the present writer, who would prefer to expand the concepts of the present subgenera and to avoid as much as possible deliberately making a nomenclatorial dustbin. Even if this is done, many species must at present remain unallocated and it seems best to recognise them as such rather than to force them into existing subgenera.

Subgenus **Leptotrombidium** Nagayo *et al.* 1916, sensu lato.

Type.—*Trombidium akamushi* Brumpt 1910:506, *Precis de Parasitologie*, 2nd. ed., Paris (915 pp.). Common and widespread on mammals and birds, especially in triangle Malaya-Japan-New Guinea.

Provisional Diagnosis (expanded).—Trombiculids whose larvae have roughly rectangular scuta, filiform sensillae with branches or barbs; palpal formula typically N/N/BNN(B) but setae on femur and/or

genu may be barbed; galeal seta nearly always branched or ciliated (but ?nude in *myzantha*); bases of chelicers typically angulated laterally (regularly in *akamushi*-group); no long outstanding nude or plumose setae on legs; larvae parasitic on mammals and secondarily to a limited extent on birds. Nymphs & Adults without eyes; precoxal plates to coxae I present (?always) and fused to form a longitudinally divided sternum. Womersley also describes a rectangular epistome with the anterior margin slightly concave or sinuous, finely denticulate; tarsi I are tapering, widest proximally.

Remarks.—This subgenus is usually taken to be synonymous with the *akamushi*-group. Womersley has restricted the larval diagnosis thus, but has accepted a number of species which fall outside it on larval characters but are included on nymphal characters. The present writer believes that there are good reasons for broadening this subgenus to include such species. The nearest relations appear to be the subgenera *Trombiculindus* and *Trombicula*, and certain unallocated species such as *T. jayewickremei* Wom., the nymph of which has no precoxal plates.

The angulation of the cheliceral bases was recorded as a character of the *akamushi*-group by Wharton (1946:173). It is occasionally present in unrelated chiggers, e.g. in some *Euschöngastia*, and may not always be present in species now included in the broad subgenus.

The diagnosis of the *akamushi*-group usually includes the specific palpal formula N/N/BNN. Species such as *T. palpalis* with palpal formula N/N/BNB are thus excluded. The writer has a specimen (species near *deliensis*) from Imphal with the palpal tarsus BNN on one side and BNB on the other. It is probable that too much insistence is placed on this feature, and that *palpalis* and related species should reasonably be placed in the *akamushi*-group. On the other hand, there is considerable variation in the scutal shape, one group showing a tendency for the PL setae to creep up the sides of the scutum away from its rounded posterolateral corners, so that the sensillary bases come to lie well behind the line of the PLs, as in *pallida*. This "*pallida*-subgroup" also shows a tendency to unusual development of the scutal (especially PL) and dorsal setae, with more or less thickening and development of heavy barbs (compare the blade-like processes of *T. baluensis* Traub & Audy, this *Study* p. 48). The members of the subgenus *Trombiculindus* (see below) have the same palpal formula (N/N/BNN) and scutal shape but the setal modification has gone much further: it is possible that there may be a close link here. With these considerations in view, we may attempt a tentative regrouping of the subgenus as shown in the following tabulation.

There is an indeterminate group comprising *jayewickremei*, *muscae*, *philipi*, *quadriense*, and *taphozous*, all of which appear to be related. All but *jayewickremei* are bat-chiggers. The nymph of *jayewickremei* has been described by Womersley under his subgenus *Neotrombicula*, without the fused precoxal plates. These species have the sensillary bases relatively close together considering the width of the scutum (cf. *gliricolens*, which Dr. Raja Varma has bred to the nymph and, in a personal communication, has placed in *Leptotrombidium*). They may be related either to *Leptotrombidium* or to *Trombicula*, probably the former.

**Old World species.*—Europe & U.S.S.R.: ?*muscae*, *russica*, *orientalis*, *pavlovskyi*, *subakamushi*. Africa: *le-gaci*, *natalensis*. Asia & Pacific: *akamushi* NA, *baluensis* T. & A., *bhimtalensis*, *bodensis* N, *burmensis* N, *burnsi*, *deliensis* NA, *dux*, *fuji*, *fulleri* N, *gliricolens*, *himizu*, *intermedia*, *keukenschrijveri* N, *kitasatoi*, *kuroshio*, *lanceolata*, *longiseta* N, *macacus*, *micula* T & A N, *miyairii*, *miyajimai*, *miyazakii*, *murotoensis*, *myzantha* N, *pallida* A, *palpalis*, *parapalpalis*, *pelta*, *pilata* T. & A., *pipellae* T. & A., *puta*, *robusta*, *scutellaris*, *sylvestris* N, *tarsala* T. & A., *tenjin*, *teramurai*, *tithwalensis*, *tosa*, *villosa*, *yasuokai*; *tanakariyoi*, *muridia*, ?*muscae*-group, *kawamurai*; 11 n. spp. to be described.

New World species.—*mexicana*, *myotis*, *panamensis*, *potosina*.

Subgenus *Trombiculindus* Radford 1948

Type.—*Trombiculindus squamosus* Radford 1948:126, *Proc. Zool. Soc., Lond.* 118, 213-272. From a rat, Himalayan range, India. —(continued on p. 143)

*In this and all following lists, the letters N, A following a name show that that species has been bred to the Nymph, Adult, to the writer's knowledge. Those with authors shown "T & A" are new species described by Traub & Audy, 1953, in this *Study*—See pp. 45-88.

TENTATIVE GROUPING OF *LEPTOTROMBIDIUM*

* Signifies that the nymph has been examined. Authors "T. & A." refer to species described by Traub & Audy, this *Study* p. .

1. **akamushi**-group sensu lato, palpi N/N/B(N?).N.N(B)

1.1 scutum normal, SBs in advance of or only level with PLs.

1.1.1 *akamushi*-subgroup

N/N/BNN

akamushi*bodensis***deliensis**pilalta* T. & A.**pipellae* T. & A.*scutellaris***sylvestris**villosa*

intermediate between 1.1.1 & 1.2.1:

*dux***fulleri***longiseta***micula* T. & A.*tarsala* T. & A.? *natalensis* (N/N/NNN)1.1.2 *macacus*-subgroup

N/N/BNB

*bhimtalensis**macacus*

?intermediate

puta (N/N/NNB)

1.2 PLs anteriorly displaced, SBs posterior to line of PLs

1.2.1 *pallida*-subgroup

N/N/BNN

(?related to *Trombiculindus*)*baluensis* T. & A.*burnsi**fuji**intermedia**kuroshio***keukenschrijveri**lanceolata**miyairii**miyazakii**murotoensis**pallida*? *tanaka-ryoi**teramurai**tosa*1.2.2 *palpalis*-subgroup

N/N/BNB

*himizu**palpalis**parapalpalis**tithwalensis**yasuokai*? *potosina* (N/B/NNB)? *miyijimai* (N/N/BBB)2. **burmensis**-group and ?others palpi B/B-N2.1 *burmensis*-subgroup

B/B/BNN

burmensis*muridia*? *miyajimai* (N/N/BBB)2.2 ?*robusta*-subgroup

B/B/NNN

myzantharobusta***gliricolens* (B/B/NNB)*pelta* (B/B/NNB)? *muscae*, ? *philipi*,? *quadriense*, ? *taphozous*

3. ??Other species, nymphs of which do not have the fused precoxal plates (some of the species listed above and known only as larvae may belong to this indeterminate group)

? *jayewickremei* (B/B/NNB)

Provisional Diagnosis (expanded).—Trombiculids whose larvae are similar to those of the *Trombicula* (*Leptotrombidium*) *pallida* subgroup (see above), but have at least the PL scutal setae and the anterior dorsal setae modified by replication or expansion (foliate). Nymphs & Adults (known only for 2 species here included for the first time in this subgenus) differing from those of *Leptotrombidium* in having no precoxal plates and in having the tectum (seen in one species only) convex instead of flat or concave distally.

Remarks.—Foliate setae have been developed in a number of unrelated groups so that a *Trombicula* might be found with foliate setae but *not* closely related to the type *T. squamosus*. To the writer, the important character is not leaf-like expansion of the setae, but simply their *modification*. The exact form of modification may vary considerably (contrast the setae of *cuneatus* with those of *squamosus* and *foliatus*). He would therefore include such species as *T. hastata* (Gater) (slightly foliate setae), as well as *T. fordii* Wom., *T. traubi* Wom., and *T. plumosa* Rad., in which the setae are otherwise modified. Shorn of their ornamental setae, all larvae appear to be indistinguishable from those of the *pallida*-subgroup. The nymphs of *hastata* and *fordii* have been described. It will be interesting to see what the nymphs of the fully foliated species are like.

World species (Asia & Pacific).—*cuneatus*, *foliaceus*, *fordii* N, *hastata* N, *plumosa*, *squamifera*, *squamosus*, n. sp. from Thailand (being described). Also *kansai* Jam. & Sasa, 1953.

Subgenus *Neotrombicula*, Hirst 1915

Type.—*Acarus autumnalis* Shaw, 1970, in Shaw & Nodder, *Vivarium Naturae, or, The Naturalist's Miscellany*, London; vol. 2, next to plate 42.

Provisional Diagnosis (sensu stricto, quoted from Wharton & Fuller 1952:56). —“ *Trombicula* in which the larvae have a pentagonal scutum, at least one mastitarsala III, normal scutal setae, and either nude whip-like or elongated feathered setae on some of the segments of leg III other than the tarsus. Adults elongated and without eyes.”

Remarks.—The type species *T. (N.) autumnalis* belongs to a distinct group with roughly pentagonal scuta and long setae which are nude, ciliated, or lightly plumose on the legs, especially on the more proximal segments. All the North American species have more than one mastitarsala III. It is difficult at present to separate this larval group from the larvae of *Blankaartia* (= *Tragardhula*). Brennan & Wharton (1950:44) in dealing with larvae of *Neotrombicula* in North America separate the two as follows:

Larvae with subequal plumose setae on the proximal segments leg III; usually parasitic on water birds; adults with eyes.

Tragardhula = *Blankaartia*

Larvae with whiplike or long plumose setae on the proximal segments of leg III; usually parasitic on terrestrial animals, especially small mammals; adults without eyes.

Neotrombicula

Womersley has however described this subgenus on the characters of nymphs and adults, which produces a much larger assemblage, the larvae of which are very heterogeneous. There are some very perplexing anomalies in this broad subgenus, suggesting that our ideas of what is or is not taxonomically important in post-larval characters may need drastic revision. The following species are included in this subgenus by Womersley:

- (a) Species known from Larvae & Nymph/Adult: *autumnalis*, *consueta*, *fordii*, *goldii*, *harrisoni*, *hastata*, *inopinatum*, *jayewickremei*, *parmifera*, *rara*, *sarcina*, *scincoides*, *spicea*, (also n. sp. near *rara*, in MS).
- (b) Species known only from Nymph/Adult, larvae unknown; *camilla*, *canestrinii*, *cavernarum*, *clavicata*, *coarcata*, *formicarum*, *manriquei*, *moesica*, *?russica*, (Vitzthum 1932, not Oudemans 1902; larva apparently unknown).
- (c) Species of larvae tentatively included by close resemblance to members in group (a): *kohlsi* (cf. *scincoides*), *munda* (cf. *spicea*), *tovelli* (cf. *scincoides*), *traubi* (cf. *fordii*).

Some of the many anomalies resulting from this grouping under the broad "post-larval" subgenus are noted below:

- (i) Species *fordi*, *hastata*, and *traubi*, with foliate or otherwise peculiarly modified dorsal setae, are not properly separable from *Trombiculindus* which is recognised as a subgenus by Womersley (see p. 141 above).
- (ii) The writer would ascribe the larvae of *goldii* and *scincoides*, as well probably as those of *kohlsi* and *tovelli*, to subgenus *Eutrombicula* (=subgenus *Trombicula*, Wom. partim). Similarly larvae of *sarcina* would be thus accommodated, because of their close relationship with larvae of *samboni*; but the nymphs and adults of *samboni* appear to be typical *Eutrombicula* (*Trombicula* of Womersley) and those of *sarcina* typical *Neotrombicula*. Wharton & Fuller (1952:47, 48) list *goldii* and *sarcina* under subgenus *Eutrombicula*; but they also include *coarctata*, known only from the adult.
- (iii) The larva of *jayewickremei* appears to be inseparable from those of some members of the subgenus *Leptotrombidium* sensu lato.
- (iv) As described elsewhere (Traub & Audy, 1953, this *Study* p. 48), there is a distinct group now recognisable related to *T. densipiliata* Walch. The nymphs of one member of this group are very close to that distinctive species *canestrinii*, known only from the adult. But the larvae are obviously different from those of the type, *autumnalis*. The same applies to such species as *spicea* and members of the *harrisoni*-group, which have larvae quite unlike those of *autumnalis* but have nymphs included in Womersley's broad subgenus.
- (v) Womersley has also described the nymph of *Heaslipia gateri* and states that this cannot be distinguished clearly from nymphs of his subgenus *Neotrombicula*.
- (vi) Species such as *T. flagellifera* Traub & Audy 1953 and *T. tuhana* Traub & Audy 1953 (pp. 46, 53, 55), have leg setae suggestive of *Neotrombicula* but their scuta and to some extent their palpal setation resemble those of *Leptotrombidium* spp.

It may be that many or even most of the species included in the broad subgenus by Womersley on account of post-larval characters should in fact be included in the subgenus *Trombicula* as provisionally redefined in the present paper. This course was not open to Womersley because he interpreted the existing drawings of *T. minor* as definitely showing the presence of eyes. As we have suggested, this interpretation may readily be a mistaken one. The present writer is not prepared to resolve any of these difficulties. It does however appear that the broad subgenus based on post-larval characters is not wholly natural. There may of course be convergence of polyphyletic groups of larvae in one direction, and of their corresponding postlarval stages in another, but this has not yet been demonstrated.

It would appear to be a sound step at this stage to recognise a true subgenus *Neotrombicula* sensu stricto, including only those species which are clearly related to the type in both larvae and nymphs, and to divide Womersley's remaining species into two groups, (a) those which appear to have sufficiently close affinities with *minor* to be included provisionally in the subgenus *Trombicula* pending further studies, and (b) those which cannot confidently be relegated to either group but which have affinities with both on the characters of nymphs and adults. This last group may be provisionally considered as ?*Neotrombicula* or ?*Trombicula* and in the lists of Old World species given by the present writer he has attempted to relegate certain species to one or other subgenus on fairly arbitrary larval characters. He does this without much confidence, but in the belief that this is one more step in the right direction.

At the same time, as many small species-groups as possible should be recognised. This has been done for the subgenus sensu stricto by Brennan & Wharton (*loc. cit.*) who have

picked out three groups, the *autumnalis*-, *microti*-, and *bisignata*-groups, characterised by the nude flagellate setae of leg III as follows (some species are ungrouped):

<i>Neotrombicula</i> .	Mastitarsala. Mastitibiala. Mastifemorala.				
<i>autumnalis</i> -group (Old World)	I	...	O	...	O
<i>microti</i> -group (New World) ...	2	...	I	...	I
<i>bisignata</i> -group ...	3	...	I	...	O

Old World species of Neotrombicula sensu-stricto.—Europe: *autumnalis*, *desaleri*, *fahrenheitzi*, *muris* (Ouds.), *pomeranzevi*, Asiatic-Pacific: *fugjimo*, *japonica*, *mitamurai*, *nagayoi*, *tamiyai*, *AX*-group (*kashmirensis*, *kanzalwanensis*, *AX* n. sp. Wom., & Audy in MS).

Old World species which may or may not be related: possibly some of those known only as adults or nymphs; possibly the *flagellifera*-*tuhana* group [see (vi) above]; possibly *naultini*, *novae-hollandiae*.

Subgenus **Blankaartia** Oudemans, 1911

= **Tragardhula** Berlese, 1912, Wom. 1948

= **Pentagonella** Thor, 1936

= **Megatrombicula** Michener, 1946

Type.—*Trombidium niloticum* Tragardh 1904:78, *Results Swedish Zool. Exped. to Egypt and the White Nile*, 1901, 20, 1-124. Adult only, from water-plants, Egypt.

Diagnosis.—Species of *Trombicula* whose larvae have a pentagonal scutum, at least one mastitarsala III but, unlike the similar larvae of *Neotrombicula*, do not possess mastifemorale and/or mastitibiale III or long lightly-feathered setae in the place of these; apparently swamp or water-frequenting, particularly parasitising water-birds*. Nymphs & Adults distinguished by having a pair of eyes lateral to and some distance from the crista (not near the sensillary bases as in *Eutrombicula*).

Remarks.—It is necessary to regard *Blankaartia* as a subgenus until its relationships with *Neotrombicula* are satisfactorily clear. *Blankaartia* may for example have developed by its special habitat adaptations from a *Neotrombicula* stem. The correct usage of *Blankaartia* instead of *Tragardhula* (used by Womersley) has been discussed by Fuller & Wharton (1952). Of the 14 species listed by Womersley (who omits only the African *T. ardeae*) five are known as larvae & nymphs/adults, viz. *acuscutellaris*, *alleei*, *attenuata*, *japonica*, *velascoi*, and two (*nilotica*, *peruviana*) as adults only. The present writer agrees with Wharton and others in placing *fugjimo*, *japonica*, *mitamurai*, *nagayoi*, and *tamiyai* in *Neotrombicula*. The remainder (*geckobia*, *gymnodactyla*, *pentagona*), all from reptiles, have 2-pronged palpal claws (undoubted *Blankaartia* species have 3) and no mastitarsala III—these form a distinct group (possibly including *incurva* & *naultini*) the relationship of which to the African *lawrencei* group (p. 147) should be investigated.

Old World species.—U.S.S.R.: *radfordi*, Africa (Egypt): *ardeae*, *nilotica* A. Asia & Pacific: *acuscutellaris* NA.

Subgenus **Eutrombicula** Ewing 1938

Type.—(*Trombicula flui* van Thiel 1930, Ewing 1938:293. *J. Wash. Acad. Sci.*, 28, 288-295; synonym) = *Acarus batatas* Linn. 1758:617. A common scrub itch mite: major hosts birds, Brazil to southern U.S.A.

Diagnosis (largely after Fuller 1952:96; = most of subgenus *Trombicula* Wom. 1952:326).—Trombiculids whose larvae have moderately large scuta, roughly rectangular, posterior border often slightly convex, usually distinctly punctate; leg III with a mastitarsala, possibly mastitibiala also; palpal claw 2-pronged, with the accessory prong medial or ventromedial to the axial; galeal seta generally nude; generally parasitic on reptiles and birds but may be on mammals. Nymphs & Adults of *Trombicula* facies but typically with eyes present, close to and slightly behind the sensillary bases (insistence on this character might be a mistake, as discussed below).

Remarks.—This has all the appearances of being a good larval genus on morphological as well as bionomic grounds, but its limits cannot yet be clearly defined. The writer suspects that the mastitarsala III and the general host-preference for reptiles and birds may be more important than details of the palpal claws. Putting aside Womersley's interpretation of *minor*

* In our collections, *acuscutellaris* appears to be associated with ricefields which are annually flooded. It is found on the ricefield-rat *R. rattus argentiventer* in suitable localities.

(see p. 138 above), he lists (his p. 327) the following nymphs/adults under the same group characters: (a) *frittsi*; (b) *alfreddugesi*, *batatas*, *helleri*, *samboni*, *splendens*, *vanommereni* Schierbeek, *wichmanni*; and (c) *jacoti* (*nom. nov.* for *Trombiculoides scaber* Jacot 1938). The last may be ignored because the larva is not known: Jenkins (1949:294) was unable to find differences between adults of *splendens* and adults identified as *jacoti* (*scaber* syn.). The larvae of *T. frittsi* are found on reptiles and a rat in the Pacific area, and (assuming a correct identity with the Malayan species from which the nymphs were bred) scorpions in Malaya; the mastitarsala III is absent and the scutum is small and pentagonal. There are many features distinguishing it from larvae of *Eutrombicula*. Furthermore the scutum of the nymph is relatively shorter than in those of group (b) while the sensillae have thickened shafts. The presence of eyes in the nymphs does not warrant including *frittsi* in this species-group: as discussed below, it may be close to *Fonsecia*.

Of the remainder, (b), the larvae are all typical *Eutrombicula*, but (i) the larva of *vanommereni* cannot be separated from that of *alfreddugesi*, of which it is now regarded as a synonym, and (ii) the larva of *helleri* can hardly be separated from that of *goldii*, of which it is regarded as a synonym*—but the adult of *goldii* is described by Womersley (p. 370) under the subgenus *Neotrombicula* as without eyes (quoting description of Boschell & Kerr 1952). This is particularly interesting because the nymph of *sarcina* is also without eyes (described under *Neotrombicula*, Wom. 1952:362), although the larva appears to be typical *Eutrombicula*. It is an amusing question as to whether we are dealing with evolutionary convergence among larvae or divergence among adults; or possibly with rudimentary eyes which require fresh material and a phase-contrast microscope for their detection. The present writer is unable to offer a worthwhile opinion. It is however likely that attempts to take post-larval characters too seriously at this early stage will often lead one astray. The writer therefore proposes to accept a group of *Eutrombicula* which do not appear to have eyes in the adult state. (It is worth noting that of three nymphs of *Eusch. lacunosa* bred out from the same *Rattus bowersi* in Malaya, one was pinkish and showed conspicuous scarlet eyespots while the other two were white and without eyespots; no eyes were however visible in any specimen after mounting. The larval pelts were indistinguishable on first examination).

African species described in this genus by Lawrence (1949:441-449), and listed under the subgenus *Eutrombicula* by Wharton & Fuller, cannot be included (Lawrence characterised the genus by the number of dorsal setae, after Ewing). Lawrence's species fall into two groups, both with 3-pronged palpal claws: (a) an *ilesi*-group from African reptiles, with pentagonal scuta, probably related to *frittsi*, comprising *aenigma*, *homopholis*, *montensis*, *rhodesiensis*, *rhopropi*, to which we should add *T. nivaria* Law. and *T. ilesi* Rad; and (b) a *lawrencei*-group, also from reptiles, with convex but not angulated posterior scutal margin, comprising *lawrencei* Wh. & F. (= *agamae* Law. preocc.), *draconensis*, *gerrhosauri*, *pachydactyli* (and ?*abyssinica* from a bird). The two groups appear to be related to each other but not to *Eutrombicula* as here defined: it may however be that this subgenus has been considered too rigidly. As discussed below, the *ilesi*-group seems to be closely related to the genus *Fonsecia* and the matter demands study. The African *lawrencei*-group may be related to the Australasian *geckobia*-group (p. 148). Without material for comparison, the writer is unable to place *E. jadini* Verc. 1953.

Jenkins (1949) & Wolfenbarger (1952) have made important studies of this subgenus in America.

Old World species (Asia & Pacific).—? *cervulicola*, *hirsti* (?= *wichmanni*) N, *isshikii*, *lygosomoides*, ? *macropus*, ? *nautilini*, ? *novae-hollandiae*, *rioi*, *samboni*, *sobrina*, *wichmanni* NA, *sarcina* (with eyeless nymphs) N; possibly related (no mastitarsala III in larvae, no eyes in nymph): *scincoides* N, *kohlsi*, *tovelli*. Also, *lumsdeni* & *watsoni* Rad. 1953.

* The probable identity of *helleri* with *goldii* is carefully discussed by Fuller (1952:141), who also (p. 117) discusses differences between *vanommereni* and *alfreddugesi*.

Subgenus **Trombicula** Berlese 1905including subgenus *Neotrombicula*, Wom. 1952, *partim*.

Type.—*Trombicula minor* Berl. 1905:155, *Redia*, 6, 346-388. Genotype; adults only from bat-guano, Java.

Provisional Diagnosis (restricted).—Larvæ without the combinations of characters of the other subgenera; scutum not broadly rectangular, but more nearly quadrate or trapezoidal, posterior margin convex (scutum almost bluntly pentagonal) or emarginate and medially convex (sinuous); sensillary bases fairly close together (SB less than $2/3$ AP); no long nude setae on legs; parasitic on mammals (type is a very small species presumably parasitic on bats.) Nymphs & Adults of typical *Trombicula* facies, without eyes (type adult very small).

Remarks.—The probable relationships of *T. minor* have already been discussed. The writer is well aware that the diagnosis given above is based on tenuous concepts. Its object is to prevent the subgenus from being used too freely as a depository for unallocated species, the writer preferring to leave such species unallocated *sub judice*. Until something better is found the writer proposes to take the new Malayan bat-chigger which has been bred to the nymph (fig. 2) as a model around which to frame this subgenus. There are good reasons to suppose that it is congeneric with *minor*. By adopting a model which can be described in detail in both larva and nymph, it will at least be possible to build up a consistent subgenus, even if it may later prove to be the wrong one (which however is most unlikely).

Those species known only from the adult and listed by Womersley under *Neotrombicula* should be held unallocated until they can be surely placed in *Trombicula*, *Neotrombicula*, or another subgenus; the cavernicolous species in particular may belong to *Trombicula*. These species are: *camilla*, *cavernarum*, *clavicata*, *coarctata*, *formicarum*, *manriquei*, *moesica*, ?*rusica* Vitzthum, 1932 (not Ouds. 1902; this adult cannot be identified with either *rusica* or *muscae* and its name may be homonym, but it might as well be left as it is for the time being).

Microthrombidium minutissimum Ouds. 1910:104 (*Ent. Ber.*, *Amst.*, 3, 103-109) from a bat in South Africa, has been redescribed by Fuller (1952:86) and we may note those characters which may be of subgeneric importance: small chiggers with a small scutum (AW 30-45 μ or less) which is nearly as deep as broad. AM advanced in front of line of ALs (anterior margin is triangular in *minutissimum*). Sensillae simply forked (or ? with very few subequal barbules). The advancement of the AM seta may readily be exaggerated in this particular chigger (cf. species of *Dolisia* sens. lat., p. 157) and it probably cannot be regarded as a subgeneric character even though in this species it gives a very distinctive inverted-pentagonal shape to the scutum. Allowing for this, the peculiar forked sensillae and the general shape of the scutum suggest a relationship with the bat-chigger *T. batui*. There also appear to be close relationships with *T. munda* and with several African chiggers related to *T. panieri* Jad. & Verc. 1952, viz., *giroudi*, *panieri*, & *rodhaini*, as well possibly with *T. schmitzi* (which has barbed sensillae).

Speleocola Lipovsky 1952 was raised to accomodate a peculiar chigger (*S. tadaridae*) from the ears of molossid bats in Oklahoma. The edges of the scutum are obscured by the attachment of cuticular striae, and the somewhat fusiform sensillary shafts are clothed in expanded setules which gives the sensillae an appearance of being lanceolate. The relations of this very interesting genus to *T. spicea* should be investigated.

Because the writer has yet had no opportunity to make a careful study of them, the species listed below are offered only as suggestions for investigation. The list includes a number of bat-chiggers, which is an interesting coincidence because the species have not been chosen for their host preferences.

Old World Species (tentative).—Europe: *minutissima*. Africa: ?*T. panieri* group (*cynictia*, *giroudi*, *panieri*, *rodhaini*). Also ?*mastomyia*, No. CORU36696 n. sp. (in *harrisoni*-group; bat, S.W. Africa). Asia & Pacific: *batui*, ?*insolli*, *minor* A, *munda*, *piercei*, ?*schmitzi*; *T. harrisoni* group (all from bats—*dimolinae*, *harrisoni* N, R17289 n. sp. Malaya). ?*T. spicea* group—? *buxtoni*, ?*khurdangensis*, *rajoriensis*, *spicea*.

Unallocated species of *Trombicula*

An attempt has been made to collect the remaining species into as many species-groups as possible. There is no doubt that many more groups will be discovered by further study. The groups presented are mostly tentative and have not been investigated deeply. Attention is drawn to the *Trombicula cynos* group described by Brennan (1952): many more studies like this are badly needed in this region.

anous-group: *anous*, *pluvius*.

geckobia-group (Asia & Pacific; almost pentagonal scutum, on reptiles; see p. 146): *incurva*, *geckobia*, *gymmodactyla*, *?naultini*, *pentagona*.

ilesi-group (Africa; pentagonal scutum; on reptiles; may be related to *Fonsecia*; see below): *aenigma*, *homopholis*, *ilesi*, *montensis*, *nivaria*, *rhodesiensis*, *rhoptropi*; *?frittsi* (Malaya, Australia).

lawrencei-group (Africa; ?related to *geckobia*-group, see p. 146): *lawrencei*, *draconensis*, *gerrhosauri*, *pachydactyli*.

leveri-group (bats): *leveri*, *revelae*.

muscae-group (bats; p. 141): *muscae*, *philipi*, *quadriense*, *taphozous*.

parmifera-group (almost pentagonal scutum, on reptiles): *parmifera*, *lundbladi*, "MAB" n. sp. in MS.

rara-group (AW:SB about 5-6:4; on reptiles, arthropods): *rara*, n. sp. nr. *rara* from pill-millipede (Wom. & Audy in MS); *?thori*.

vorca-group (mostly on birds): *?corvi*, *?canestrinii*, *densipiliata*, *nissami*, *?strinatii*, *vorca* Traub & Audy 1953 (this *Study* p. 48) (& *thompsoni* Brennan from U.S.A.).

Ungrouped species.—Europe: *clavicata* A, *formicarum* A, *moesica* A, *vernalis*, *willmanni* W. & F. (= *multisetosa* Will.), *zachvatkini*. Africa: *boaedonia*, *bruynoghei*, *centropodis*, *claviglia*, *claviglicola*, *guineense*, *jadini*, *microps*, *nigeriensis*, *praomyia* (p. 160), *rhodesiana*, *scapulosa*, *sicei*, *subquadrata*, *sulae*, *tragardhi*. Asia & Pacific: *ablephara*, *consueta* N, *jayewickremei* N (p. 141), *jubbulporensis* (see p. 160), *kalrae*, *southcotti*, *vietzi*; *agamae* André.

Genus *Fonsecia* Radford 1946

Type.—*Trombicula ewingi* Fonseca 1932:153, *Mem. Inst. Butatan S. Paulo*, 7, 151-158. From a snake, Brazil.

Diagnosis.—*Trombiculines* of the *Trombicula* group whose larvae have at least the anterolateral scutal setae (ALs) modified by reduction to peglike or short expanded processes; scutum shield-shaped, roughly as broad as deep, bluntly pentagonal; parasitic on reptiles, possibly exclusively on snakes.

Remarks.—A new species from Malaya is being described (Audy 1955, in MS) in which the modification of the setae is carried on to involve the PL setae and the anterior rows of dorsal setae as well. The AL setae are peculiarly modified in a way suggestive of those of *F. travassosi* Fonseca. The PL setae and anterior dorsal setae are modified more simply by basal swelling, like the setae of *Euschöngastia causicola* (Jadin & Verc.). This group is sufficiently distinct in both morphology and host-preference to be recognised as a genus. It appears to be closely related to the *ilesi* group (*T. ilesi* itself also being from a snake) and indeed the two groups may later prove to be congeneric.

The modification of these setae is extremely interesting. There are very many examples to show that the PL scutal setae and the anterior dorsal setae are genetically linked and develop under the influence of the same organiser (using this term in the embryological sense). When setal modifications in this PL-DS field are extensive, they may involve the AL setae also, but rarely the AM. The genus *Fonsecia* illustrates modification of the other organiser field, the ALs alone being modified in *ewingi* & *coluberina*, and both ALs & AM in *travassosi*, while the extensive modification in the new Malayan species secondarily involves the PL-DS field in producing a less developed modification of those setae, while the AM seta is unmodified. A study of the many chiggers with foliate setae shows that modification in the PL-DS field does not usually extend to those post-and para-anal setae which we describe as "caudal setae" (CS), where presumably the influence of the VS-field is felt. Similarly, the humeral setae (HS) which often differ from the dorsal setae in both larvæ and nymphs, appear to be influenced by the coxal field (we may note the tendency for multisetose coxae to be associated with multiple humeral setae, e.g. in *Dolosisia* sensu lato, p. 157).

The inference is that, being influenced by different organiser fields, the detailed differences between the AM-AL, the PL-DS, the humeral setae (HS), the caudal or postanal setae (CS), and the ventral setae (VS) are of taxonomic importance, and there is support from several sources for the plea made by Audy (1952) that the caudal setae be compared with and enumerated separately from the ventral setae. A further inference is that the PL setae virtually represent dorsal setae but are customarily placed on the scutum. The retraction of the scutum to isolate these setae, or its extension so as to include extra dorsal setae, may be reasonably anticipated; and of course it does occur.

World species.—Asia: *coluberina*, CORU.35961 n. sp. Audy in MS. South America: *ewingi*, *travassosi*.

Genus **Tecomatlana** Hoffman 1947

including **Sauriscus** Lawrence 1949

Trisetica Traub & Evans 1950

Type.—*Tecomatlana sandovali* Hoffman 1947:452, *An. Escuela nac Cienc. biol., Mex.*, 4, 451-457.

Diagnosis.—Species related to *Trombicula*, whose larvae have the PL setae displaced off the scutum.

Remarks.—*Sauriscus ewingi* Law. is from lizards in Africa; it has a shallow scutum, finely barbed sensillae, single eyes, a 2-pronged palpal claw. *Trisetica melvini* Traub & Evans is from a bat-cave in North Burma; it has a deeper scutum, a peculiar thickened sensilla, double eyes, slender elongated claws with 3 subequal prongs. *Tecomatlana sandovali* is from bats in Mexico; it has a scutum like that of *melvini*, but normal sensillae with barbs in the distal half, a short axial prong and 3 short accessory prongs to the claws. The writer believes that it would be a mistake to assume that these three must be congeneric simply because they share a recurrent character (PLs off the scutum) which might have developed independently from unrelated progenitors. He therefore intends to preserve *Sauriscus* and *Trisetica* as subgenera until further studies clarify matters.

Genus **Myotrombicula** Womersley & Heaslip 1943

Type.—*Myotrombicula vespertilionis* Wom. & Heaslip 1943, *Trans. R. Soc. S. Aust.*, 67, 68-142. From bats, Australia.

Diagnosis.—Monotypic: Larva with broad shallow scutum but nature of sensillae not known; cheliceral blade modified (short, stumpy, with two large blunt teeth); palpi somewhat modified (laterally angulate, strongly incurved).

Remarks.—Wharton & Fuller (1952:84) state that "if the type species has expanded sensillae, *Myotrombicula* might be a synonym of *Oenoschöngastia*," but the present writer would not subscribe to this view because *Myotrombicula* has a completely different shape of scutum, no mastitarsala III, and the chelicers are differently modified: there are probably a number of other differences, e.g., in the leg chaetotaxy.

Genus **Heaslipia** Womersley 1952

Type.—*Trombiculoides gateri* Wom. & Heaslip 1943:101, *Trans. R. Soc. S. Aust.*, 67, 68-142. From rats, highlands of Malaya.

Diagnosis.—Monotypic: larva with scutum not extended posteriorly but including additional setae (4); mastitarsala III present. Nymph of typical *Trombicula* (*Neotrombicula* of Womersley) facies, without eyes, and a large triangular tectum.

Genus **Novotrombicula** Womersley & Kohls 1947

Type.—*Novotrombicula owiensis* Wom. & Kohls 1946:4, *Trans. R. Soc. S. Aust.*, 71, 2-12. From soil, island off New Guinea.

Diagnosis.—Monotypic: larva with scutum extended posteriorly, with unexpanded sensillary bases anteriorly placed, and (2) additional posterior scutal setae (i.e., more than the usual 5) as in *Schöngastiella* and *Gahrlepiea*; mastitarsala III absent.

Remarks.—*Novotrombicula* and *Heaslipia* have a major character (additional posterior scutal setae) in common but this has clearly developed independently. The anterior part of the scutum of *Novotrombicula* resembles that of *T. rara* and *T. thori*, common on skinks, in the placing of the sensillary bases; this and the absence of a mastitarsala are probably of generic importance.

Genus *Ipotrombicula* Womersley 1952

Type.—*Trombicula elegans* Wom. 1942:173, *Rec. S. Aust. Mus.*, 7, 169-181. Adults only; sea-shore, Australia.

Diagnosis.—Monotypic, adults only: as described by Womersley 1952:323, *Rec. S. Aust. Mus.*, 10, 1-435.

B.—*Schöngastia* GROUP OF GENERA—EXPANDED SENSILLAE

Genus *Schöngastia* Oudemans, 1910

Type.—*Thrombidium vandersandei* Ouds., 1905:216, *Ent. Ber., Amst.*, 1, 216-218. From man, rats, birds in eastern Indonesia, New Guinea, Solomon Is.

Diagnosis (restricted).—Trombiculines whose larvae have 7-segmented legs; shield-like scutum with markedly convex posterior margin, 5 scutal setae, sensillary bases fairly close together, and globose sensillae; a series of teeth on the chelicers (which are usually long), and a nude seta or mastitarsala on tarsus of leg III (?? may not always be present); apparently restricted to the Old World tropics and sub-tropics; primarily parasitic on reptiles and often on birds, sometimes extending to mammals and including two important scrub-itch mites. Nymphs and Adults (known from 2 or 3 species: *schuffneri*, *vieta*, *maldiviensis*) without eyes, with the sensillary area about as wide as long, roughly triangular with apex directed backwards, SB relatively fairly wide (ASL/SB ratio 2); tectum rounded; sensillae nude or lightly barbed; precoxal plates present on coxae I. Not recorded from the New World.

Remarks.—This genus has been "defined" on a key-character (toothed chelicers) instead of being based on relationships with the genotype. What appears to be a good natural group of (larval) generic status has thus been confused by the inclusion of outsiders. It seems best to restrict the genus as rediagnosed above to the clear group-characters of the *vandersandei* species-group, viz., the triad, scutal shape, toothed chelicers, and mastitarsala III, added to the general host-preference for birds and reptiles. The general appearance of the scutum closely resembles that of the *lanius*-group (new subgenus *Helenicula* below). Dr Lawrence (in correspondence) describes a mastitarsala III near the base of the joint, clearly visible in his *S. platysauri*, *S. pseudocordyli* and *S. scincicola*, but he could not see this in the other species (see lists below). Varma (*in litt.*) is describing a new *Schöngastia* from near Calcutta: it has the typical almost-pentagonal scutum and the mastitarsala.

There is no doubt that a large number of ill-sorted chiggers are related to *Schöngastia* and Womersley has made this a major genus sensu lato. The writer feels that this group is well characterised in the larvae and is not the best choice as the typical subgenus of a heterogeneous group which is almost certainly destined to be split up into several genera in spite of apparent similarities between the post-larval stages. He therefore prefers to recognise *Schöngastia* sensu stricto and *Euschöngastia* sensu lato, the latter including a heterogeneous collection and corresponding to the other heterogeneous genera *Trombicula* sensu lato, *Gahrlepiea* sensu lato.

Three species at least (excluding Lawrence's species ? without mastitarsalæ, noted above, which require close study) are not congeneric. *Schöngastia oudemansi* Gater is quite distinct on a number of characters and while approving of Fuller's action in placing it in a new (and at the time monotypic) genus, *Walchiella*, it is unfortunate that this particular name was chosen because for reasons already discussed we cannot attach sufficient importance to the number of leg-segments to include this species in the *Gahrlepieinæ*: its affinities are clearly with *Euschöngastia* (see p. 153 below).

Womersley's species *bidentata*, of which Mr Womersley has kindly sent us a specimen, is very distinctive and not congeneric: it must be accommodated in *Euschöngastia* despite the blunt

teeth on the chelicer, the presence of which alone is not a generic character. Similarly, *S.(S.) oculicola* Wom. 1952 is not congeneric and as discussed elsewhere (below, and by Audy, in MS) it is probably best accommodated in *Dolosisia* sensu lato because in larva and nymph it shows much closer affinities with this genus than it does with the type of *Euschöngastia*.

Of species in Wharton and Fuller's list, *S. jamesi* Gun. is a synonym of a true *Neoschöngastia*, *N. yeomansi* Gun.; and *S. katonis* Wom and Heaslip is a synonym of *S. schüffneri* (vide Womersley, 1952:257, 159). These authors synonymise *blestowei* Gun. with *vandersandei*, and *S. maldiviensis* Rad. with *S. vieta* but Womersley retains these as species. In the case of *maldiviensis* there appear to be differences in both larvae and nymphs, and it would probably be correct to regard this species as a true island subspecies of *vieta*.

As *Schöngastia* appears to be an Old World genus, the list below includes the world species. Some of Lawrence's species are included provisionally because of the scutal shape and reptilian hosts, the question of the nude seta on tarsus III being *sub judice*. Five others African species are recorded from mammals. *S. andrei* Rad., *S. cercopithecii* (Trag.), and *S. willmanni* Rad., have the general appearances of this genus but their descriptions are lacking in a number of data. Fuller (1948) redescribes *cercopithecii* and notes the presence of mastitarsala III; Mr E. Browning of the British Museum (Natural History) has kindly examined *andrei* and *willmanni* and states that *andrei* has two mastitarsalae III and *willmanni* one. *S. lavoipierrei* Jadin and Vercammen-Grandjean, 1952:621, is a typical *Schöngastia* with one mastitarsala III. *S. oubanguiana* André 1951, also from mammals, has the characteristic scutum and toothed chelicers, but tarsus III is not described and the presence or absence of a mastitarsala III is uncertain; two sensory rods are mentioned and drawn for tarsus I but as the microtarsala is not noted, it may be that in this species the microtarsala I is exceptionally elongated. A detailed study of the legs would be interesting.

World Species.—Africa: *andrei*, *cercopithecii*, *platysauri*, *pseudocoryli*, *scincicola*, *willmanni*, probably *gerrhosauri*, *mabuyana*, *monticola*, *oubanguiana*. Asia and Pacific: *blestowei* (?), *philipi*, *pseudoschuffneri*, *schuffneri* N (= *pusilla*); *taylori*; *vandersandei* (? = *blestowei*); *vieta vieta* N & v. *maldiviensis* N (assuming provisionally that the latter is a geographic "island" subspecies, which appears likely); *whartoni*; "BP" n. sp., Varma in MS. Also *haddowi* Rad. 1953 (hyrax, Africa).

Genus *Oenoschöngastia* Womersley and Kohls, 1947

Type.—*Oenoschöngastia cana* Wom. & Kohls, 1947:8, *Trans. R. Soc. S. Aust.*, 71, 2-12. From nest of ground-bird, New Guinea.

Diagnosis.—Monotypic: larva similar to those of *Schöngastia* but chelicers differently modified (short, stout, curved and stumpy with several apical prongs). Nymph unknown.

Genus *Radfordiana* Womersley, 1953

Type.—*Radfordiana rostrata* Wom., 1952:242, *Rec. S. Aust. Mus.*, 10, 1-435. From soil, nest of ground-bird, and lizard, New Guinea.

Diagnosis.—Monotypic: larva similar to *Schöngastia* but chelicers differently modified (very long, serrated, almost styliiform); hypostome long, tongue-like, palpi long and slender, palpal claw a single prong; sensillary bases posterior to line of PLs.

Remarks.—In the general scutal shape, the presence of a mastitarsala III, and host-preferences (birds and reptiles) both *Oenoschöngastia* and *Radfordiana* are very close to *Schöngastia* s. str. The modification of the chelicers already present in *Schöngastia* appears to have been carried further in these two species. The writer believes it best to *think* of these two genera as being subgenera of *Schöngastia*.

Genus *Euschöngastia* Ewing, 1938, expanded

Type.—(*Euschöngastia americana* Ewing, 1938:293, *J. Wash. Acad. Sci.*, 28, 288-295, synonym) = *Schöngastia sciuricola* Ewing, 1925:261, *Amer. J. trop. Med.*, 5, 251-265. From squirrels, U.S.A.

Provisional Diagnosis (sensu lato, roughly equivalent to subgenus *Ascoschöngastia*, Wom. 1952:170).—Trombiculinids whose larvae have variously shaped scuta, 5 scutal setae and expanded sensillae (globose or lanceolate); legs usually 7-segmented but occasionally legs II and III 6-segmented; chelicers only

rarely serrated or with teeth; wide host range but mostly on mammals. Nymphs and Adults similar to those of *Schöngastia* but with eyes and precoxal plates absent or completely fused to form a sternum, in species so far examined.

Remarks.—As discussed in a footnote by Womersley (1952:170) and reaffirmed in a paper to be published (Womersley and Audy, 1955) *Euschöngastia* has priority over *Ascoschöngastia* and the former should be extended to include all those chiggers which have been included in *Schöngastia* (*Ascoschöngastia*) by Womersley (*loc. cit.*). Womersley's intention in this matter is quite clear (private communication), and evidently the amendment of his monograph proved impracticable.

The writer believes that *Schöngastia* sensu stricto discussed above is a valid genus. The assortment of chiggers included by Womersley in his subgenus *Ascoschöngastia* (amended to *Euschöngastia*) are therefore here treated as a genus, *Euschöngastia* sensu lato.

As noted below, however, the type (*E. sciuricola*) belongs to a species-group which has hitherto been distinguished by the accessory apical prongs to the palpal claws. Although the number of prongs on the claws is by itself a variable character of doubtful significance, this species-group appears to be distinctive in other ways and the writer doubts if such species as *E. lacunosa* (Gater) and *E. indica* (Hirst) will ultimately prove to be congeneric with it. Usage however dictates that *Euschöngastia* should for the time being taken as the temporary repository. As with *Trombicula* it appears to the writer that the proper procedure here is to attempt to define the type subgenus fairly strictly, and to recognise as many distinct species-groups and possible subgenera as may be necessary. A number of species will for a time inevitably remain unallocated to a group within the genus. As a step in the stabilisation of these affiliated groups, a new subgenus is here raised to accommodate the well-knit *lanius-mutabilis*-group. It will probably be helpful to raise another subgenus for the *indica*-group also, but this would at present be premature, because the *indica*-group might prove to be congeneric with *Dolosisia*.

Subgenus **Euschöngastia** Ewing, 1938

Type.—(*Euschöngastia americana* Ewing, 1938: 293, *J. Wash. Acad. Sci.*, 28, 288-295, synonym) = *Schöngastia sciuricola* Ewing, 1925:261, *Amer. J. trop. Med.*, 5, 251-265. On American rodents.

Diagnosis.—Larvae with a characteristic shaped scutum, generally broader than long, with PW appreciably wider than AW and the posterior margin medially convex; palpal claws variable but generally with several small apical accessory prongs, 4-6 in number (these may vary in number even on both sides of the same specimen, and may be obscured by the main axis of the claw); so far not recovered from the Asiatic-Pacific area.

Remarks.—It might be a mistake to insist on the regular presence of the apical prongs on the palpal claws in the diagnosis of this subgenus. Certain African species appear to be related, but have 3-pronged claws. These are *aethomyia*, *otomyia*, and two species very near to these sent to the writer by Dr. Lawrence: the latter species have a mastitibiala and a mastitarsala III, both very fine and tapering, but the writer has been unable to compare them with any of the described species.

Subgenus **Helenicula** nov.

Type.—*Neoschöngastia lanus* Rad., 1946:261, *Proc. Zool. Soc. Lond.*, 116, 247-265. From a bird and rats, Indo-Burma border.

Diagnosis.—Larval *Euschöngastia* with shield-shaped scuta with convex posterior margins (cf. *Schöngastia* s.s., but emarginate in *signata*) and sensillary bases very close together (ca. 15 μ , or considerably less than twice the diameter of the bases, apart), globose sensillae, with basal stem; generally with multisetose coxae III (1-setose in *signata*); without mastitarsala III. Several species appear to be widely distributed and there is evidence suggesting that larvae of this subgenus are seasonal, appearing in relatively cold dry seasons. Nymphs & Adults (based on 4 species) with the general characters of *Euschöngastia* but with thickened and well-barbed shafts to the sensillae, a relatively narrow sensillary area (ASL/SB ratio 2.3-2.8). The posterior dorsal setae in *mutabilis* and *signata* have a long terminal setule. Not recorded from the New World.

Remarks.—This is the *globulare*-group in Womersley's Key (1952:231). The dry-seasonal appearance of larvae of this group has been noted elsewhere (Audy, 1947; 1953, table 4; Audy *et al.* 1953). The writer has pleasure in naming this subgenus for his mite of a daughter. A revision of the subgenus is to be published with the description of further nymphal material. The inclusion of the two African species listed below is subject to confirmation.

Old World species.—Africa: ?? *madecassa*; ? "SGH" n. sp. Jad. & Verc., 1953 in press. Asia and Pacific: *covelli*, *comata*, *globulare*, *kohlsi* N, *lanius* N, *miyagawai*, *mutabilis* N, *signata* (N unpub.).

Subgenus **Walchiella** Fuller, 1952, modified.

Type.—*Trombicula oudemansi* Walch, 1922:35, *Geneesk. Tijds. Ned. Ind.*, 62, 530-588. From mammals Malaysia and ?Australasia (type from Sumatra).

Provisional Diagnosis (expanded).—Larval *Euschöngastia* species close to those of the *lacunosa*-group (below) differing from them in having the femora of legs II & III undivided, these legs therefore 6-segmented instead of 7-segmented; chelicerae sometimes toothed or serrated, often simple, scutum well-chitinated and roughly rectangular but with posterior margin laterally rounded; bases of body-setae well-chitinated, generally conspicuous (DS set in platelets in *heaslipi*, *traubi*), setae often fairly short with inconspicuous barbules, and a general tendency for the DS to vary in length according to position; without a mastitarsala III. Nymphs & Adults (known only for *oudemansi* and n. sp. undescribed) apparently with fine nude sensillae (cf. *S. vieta*), sensillary area fairly broad relative to crista (ASL:SB ratio about 1.9); not clearly distinguishable from those of other groups of *Euschöngastia*. Not yet recorded outside Asiatic-Pacific area.

Remarks.—The type species, *E. oudemansi*, is a dominant chigger on ground-dwelling animals in the Malayan forest (see Table 1) and it can now be recognised as the dominant member of a considerable and widespread species-group. *E. oudemansi* itself has, as originally described by Walch, a row of distinct teeth and typical Malayan material shows these clearly [not as figured by Womersley, 1952, fig. 32C, which is probably the chelicer of *E. impar* (Gunther, 1939)] Dr. D. J. Lee of Sydney University has kindly allowed the writer to study a paratype of Gunther's *impar*, while Womersley has kindly lent a whole series of slides of material from New Guinea. From a study of these, it would appear that two distinct forms have been confused: one, *impar*, is without teeth to the chelicers (or perhaps with minute serrations ?) while the posterior dorsal-setae of the nymphs have very long subterminal setules; the other, typical *oudemansi*, has recognisable cheliceral teeth and the subterminal setules are relatively short. The scuta appear to be shaped somewhat differently. Whether or not these two forms (which may occur in the same locality) are two species or only varieties or subspecies now overlapping, the writer is not prepared to discuss. Until the material has been studied, it would be advisable to regard *impar* as a valid species, or at least as a distinct form.

E. oudemansi is a very small species, and in the small nymph the setation of the legs is simplified. This gives what may be false air of distinction to the chaetotaxy and it is hoped that a large species like some of those from Borneo may be bred in the near future.

Although the writer believes that *Walchiella* is probably a good larval genus, it is not possible to separate it generically from the *lacunosa*-group and until the two groups have been studied closely it would appear best to treat *Walchiella* as a sister group, i.e. as a subgenus.

World species (Asia & Pacific).—*asonluca* Traub & Audy, 1953 (this *Study* p. 84), *calunosa* Traub & Audy, 1953 (*ibid.*, p. 84), *heaslipi*, *impar*, *lewthwaitei*, *oudemansi*, *traubi*, 5 species being studied (one species bred to nymph).

Subgenus (?**Walchiella**): **lacunosa**-group

Representative Species.—*Neoschöngastia lacunosa* Gater, 1932:156, *Parasitology*, 24, 143-174. Common on ground-living rats in Malayan forest.

Provisional Diagnosis.—*Euschöngastia* species whose larvae differ from those of *Walchiella* in having all legs 7-segmented, but which otherwise share the following characters: scutum well-chitinated, punctate, roughly rectangular but PW often wider than AW; anterior and lateral margins nearly straight, posterior margin characteristically flattened or slightly concave medially and convexly rounded laterally towards the PLs; sensillae clavate to lanceolate; bases of body-setae well chitinated; a tendency for scutal and dorsal setae to vary considerably in relative length from species to species; without a mastitarsala III. Nymph described for only one species (*lacunosa*): a typical *Euschöngastia*. Not recorded from the New World.

Remarks.—Both the *oudemansi*- and the *lacunosa*-group are immediately recognisable by the general appearance of the scutum. There is a most convincing similarity which is difficult to convey by illustrations or words. There is wealth of material from Malaysia and Australasia and it is premature to discuss this group until further studies have been made. We need only note that it is exceptional for members of the *oudemansi*-group to have toothed chelicers, and that femora II and III are imperfectly divided in several members of the *lacunosa*-group. Therefore we either have an extraordinary close convergence in two different groups, or they are but one, and the *lacunosa*-group should be included in *Walchiella*, which may then be restored to generic rank.

World species (Asia & Pacific).—*lacunosa* NA, *plawrencei* (= *guntheri*), *nadchatrami* N, *phascogale sarawakensis*, *smithi*, *wongabelensis*, 4 n. spp. in MS.

? New subgenus: **indica**-group

Representative Species.—*Schöngastia indica* Hirst, 1915:187, *Bull. ent. Res.*, 6, 183-190. Common and widespread, especially on rodents (including house-rats) in Asiatic-Pacific area.

Provisional Diagnosis.—Species of *Euschöngastia* whose larvae have small subquadrate scuta, usually lightly chitinated, with AW 20-50 μ and AP 20-30 μ (?except in *rattus*, AP 42); AM in advance of ALs with the shoulders of the scutum rounded in front of ALs; AM longer than ALs; posterior scutal margin sinuous or slightly convex; sensillary bases about centrally placed, sensillae clavate with a basal stem, not globose; eyes present or absent; legs usually short with relatively thick, stumpy segments, frequently with one or more nude setae on tarsus III, body and leg setae usually delicately barbed or ciliated, not stout or plumose. Nymphs & Adults (described for *indica*, *audyi*) apparently not distinctive, of general *Euschöngastia* facies with ASL: SB ratio almost 2; sensillae hirsute, slightly thickened in *audyi*. N.B.: *debilis*, *labuanensis*, are exceptions noted below.

Remarks.—*Eusch. indica* is the dominant species infesting domestic rats in villages and towns from India to Malaysia and the Philippines; its range extends to Guam and New Guinea. In Malaya it is also a dominant species infesting tree-nesting rats in plantations and the forest-edge, but within the forest it is replaced by *audyi*, which was first collected in South Burma in 1945. *E. audyi* is red (*indica* being white) and it is a dominant chigger on arboreal mammals in the forests in Malaya and Borneo. Gispén (1950) has recovered pathogenic rickettsiae from *indica* in Java, and Traub *et al.* (1950) have recovered *R. tsutsugamushi* from a species from Malayan squirrels recorded as *indica* but subsequently described as *audyi* (see footnote, Traub and Audy, 1953, this *Study* p. 77). This is clearly an important group. A good deal of nymphal and new larval material is at hand and its study may allow the limits of this group to be defined. It is necessary to clarify the relationships between the *indica*-group as here defined and (a) the uncertain genera *Ascoschöngastia* and *Pseudoschöngastia* and (b) such species as *debilis* and *labuanensis*, and (c) the genus *Dolosisia* sensu lato. It is worth noting the extraordinarily close resemblance between *Trombicula munda* and *Euschöngastia indica*—they are very easily confused if the sensillae are missing: there has been a very close convergence of characters in the larvae of two genera. *E. labuanensis* is very close indeed to *E. roluis* Traub and Audy, 1953 (this *Study* p. 79), but (sensillae excluded) it differs from it no less than *T. munda* differs from *E. indica*. It is clearly necessary to be cautious and the present writer would prefer to leave *debilis* and *labuanensis* *sub judice*. In both, the AM seta is in line with or slightly behind the line of the ALs and the anterior scutal shoulder is lacking; in *labuanensis* the concave posterior margin suggests a possible relationship with such species as *E. andrei*. There may be confusing intermediate forms linking the *indica*-group to *Dolosisia* and there appear sound reasons for regarding *Ascoschöngastia* at least as a sister group.

The exceptional depth (AP 42 μ) of the scutum of *E. rattus* appears to be partly due to a fracture in the very poorly chitinated scutum, visible under the phase-contrast microscope in a paratype kindly lent to the writer by Womersley.

Old World species (Asia & Pacific).—*audyi* N (A unpub.), *daria* T. & A. (N unpub.), *indica* NA (= *cockingsi* N), *indicella* T. & A., *lorius*, *ocellifera* T. & A., *roluis* T. & A. (N unpub.), *rattus*, *soekaboemiensis*, 2 n. spp. unpub. (species with authors T. & A. are new species, this *Study* pp. 77-88).

Unallocated species of *Euschöngastia*

See comments to unallocated species of *Trombicula*, p. 148.

foliata-group: *foliata*, *mccullochi*, *pseudomys*, *uromys*.

?lappacea-group: *?cassiope*, *edwardsi*, *lappacea*, *?queenslandica*, *womersleyi*.

?mohri-group (? ?related to *lacunosa*-group): *crinita*, *mackerrasae*, *mohri*, *rectangulare*.

otomyia-group: *aethomyia*, *otomyia*, n. sp. CORU 3711.

raui-group: *raui*, *innisfailensis* (= *bushlandi* syn); n. sp. Wom. & Audy in MS.

?similis-group: *dasycerci*, *derricki*, *perameles*, *similis*.

Ungrouped species.—Europe: *?berlesei*. Africa: *africana*, *alticola*, *annulata*, *?bottegi*, *brevipalpis*, *capensis*, *causicola*, *gerrhosauri*, *kalaharica*, *laurenti*, *longispina*, *matoppoanus*, *monticola*, *ophicola*, *origensis*, *rhabdomyia*, *rhodesiensis*, *transvaalensis*, *tropidosauri*, *viperina*. Asia & Pacific: *antipodianum*, *bidentata*, *cairnsensis*, *coorongensis*, *echymipera*, *hirsti*, *ikaoensis*, *lipoxena*, *madagascariensis*, *melomys*, *peregrina*, *philippensis*, *samboni*, *samoensis*, *setosa*, *trichosuri*, *westraliense*. Also *schlugeri* Rad. 1953 (India), and *kitajimai*, F. & Ob. 1953.

Genus *Ascoschöngastia* Ewing, 1946

Type.—*Neoschöngastia malayensis* Gater, 1932:158, *Parasitology*, 24, 143-174. Apparently host-specific to the tree-living rat *Rattus canus* in Malaya.

Diagnosis.—Trombiculids with the characters of *Euschöngastia* whose larvae have the PL setae off the scutum. Nymph (of *malayensis*) an undistinguished *Euschöngastia*.

Remarks.—This group may be clearly separated from *Euschöngastia* sens. str. and it will doubtless accumulate related species around it—possibly even some with the PLs on the scutum. It would be consistent in this paper to treat it as a subgenus of *Euschöngastia* but the present writer would hesitate to interfere again with this group, which has suffered a lot of taxonomic indecision. The relationships of the *indica*-group (p. 154) and of *Pseudoschöngastia* to this genus should be particularly well studied. Nor should species be automatically placed in it only because they have expanded sensillae and PLs off the scutum.

Old World species.—Africa: *aethiopica*. Asia: *capillata*, *malayensis* N, *masta*, “NOV” n. sp. Wom. & Audy in MS.

Genus *Pseudoschöngastia* Lipovsky, 1951

Type.—*Pseudoschöngastia hungerfordi* Lipovsky, 1951:95, *J. Kansas ent. Soc.*, 24, 95-102. From small mammals in U.S.A.

Diagnosis.—Trombiculids with the characters of *Euschöngastia* whose larvae have PLs off the scutum and also legs II and III 6-segmented; so far all from the New World.

Remarks.—This group seems to bear the same kind of relationship to *Ascoschöngastia* as *Walchiella* bears to the *E. lacunosa* group. The writer believes that its affinities lie with *Euschöngastia* and not with any of the gahrlepiines (walchiines). He also believes that (a) its generic status requires more confirmation, but (b) it would be foolish to do anything but leave it as a genus at the present stage of fluidity in concepts. Opinions as to the relative value of characters such as displacement of the PL setae and the leg segmentation are almost entirely personal and have not yet been tested by time. The sister genus *Walchiella* is not related and has temporarily been accommodated as a subgenus of *Euschöngastia* because it is not properly separable from the *lacunosa*-group. The new Malayan species noted under *Ascoschöngastia* shows a very indistinct division of the femora of legs II and III in some specimens, and the present writer has not been impressed with this character while studying the *oudemansi*- and *lacunosa*-groups.

Genus *Neoschöngastia* Ewing, 1929

Type.—*Schöngastia americana* Hirst, 1921:37, *Ann. Mag. Nat. Hist.*, 17, 37-39. From various birds and a lizard, North and Central America.

Diagnosis (after Wharton & Hardcastle, 1946 and Womersley, 1952).—Trombiculines of the *Schöngastia* generic group with scutum submerged in the striated cuticle, sensillary areas usually below a transverse ridge; chelicers with only dorsal tooth and recurved ventral tooth; coxa III sometimes

multisetose; mastitarsala III sometimes present; apparently confined to birds. Nymphs (known for 4 species) with sensillary area striated and entire not raised between sensillary bases to form longitudinal ridges; sensillary area reniform, hilus anterior; sensillae variable, lanceolate or almost filiform; eyes absent; opisthosomal setae of two types, long and short.

Remarks.—There is a great range of variation in this genus, in such characters as the shape of scutum and sensilla, and the setation of the palps, galea, scuta, coxae, and body. As Wharton & Hardcastle point out, the three species *carveri*, *namrui*, and *riversi* are so distinctive that “each could conceivably be made the type of a monotypic genus... on morphological grounds”. One of the four nymphs known is that of the distinctive *carveri*. The extraordinary association of the submerged scutum with exclusive parasitisation of birds is striking, but we may note that *E. rectangulare* from a rat has the scutum likewise partly submerged. The scutal submergence might be one of those perplexing examples of convergence which seem to occur in the chiggers—e.g. the very close similarity between *T. munda* and *E. indica* with occur together on house-rats in Malaya. A group which parasitises birds is exposed in both larval and post-larval stages to a particularly interesting complex of environments and the intensive study of this genus will undoubtedly be as fascinating as it will be instructive. An important question is whether this genus is regularly nest-infesting, i.e. whether the post-larval stages infest the nests, as appears generally to be the case with *E. indica* for example.

Old World species.—Africa: *mirafra*. India & Malaysia: *gallinarum* N, *salmi*, *thomasi*. Pacific area: *americana solomonis* N?, *atollensis*, *backhousei*, *bougainvillensis*, *carveri* N, *dubia*, *egretta*, *gallinarum* N, *monticola* N?, *namrui*, *pauensis*, *posekanyai*, *retrocincta*, *riversi*, *strongi*, *yeomansi*; *asakawai*, *okumurai*.

Genus **Mackiena** Traub & Evans, 1950

Type.—*Mackiena empodiformis* Traub & Evans 1950:126, *J. Wash. Med. Sci.*, 40, 126-219, from a bird, North Burma.

Diagnosis.—With the characters of *Neoschöngastia* but with empodium expanded to sucker-like or pad-like terminal discs.

Remarks.—This genus is probably best thought of provisionally as a subgenus of *Neoschöngastia*. There is no reason to suppose that the modified empodium alone relates this species to *Riedlinia*.

Genus **Guntherana** Womersley & Heaslip, 1943

Type.—*Neoschöngastia kallipygos* Gunther, 1939:183, *Proc. Linn. Soc. N.S.W.*, 64, 73-96 (synonyms *N. callipygea* Gun., 1939, *N. bipygalis* Gun., 1939, *G. parana* Wom., 1944). From rats and marsupial rats, New Guinea.

Diagnosis.—Trombiculines of the *Schöngastia* generic group whose larvae have paired posterior dorsal plates bearing pairs of setae on each side (the plates may appear fused in unengorged larvae); body often slightly constricted medially; eyes present; without mastitarsala III. The only known larvae (of the type) hatch from eggs cemented to the fur of the hosts. Nymphs & Adults similar to those of *Euschöngastia* but with sensillary area relatively very wide (ASL/SB=about 1.1); shallow posterior angle; sensillae unexpanded with barbs or ciliations along entire length of shaft; without eyes; precoxal plates of coxa I well defined, separated (no true sternum); dorsal setae slender, tapering, ciliated.

Remarks.—There is some difference of opinion on the correct name for the type, which was described as *N. kallipygos*. Gunther's amendment to *N. bipygalis* (*nom nov.*, Gunther, 1939, *Proc. Linn. Soc. N.S.W.*, 64, 471-473) is not acceptable as it was made for no valid reason, as Gunther himself accepts in his recent check-list.

Gunther (1952:2) has raised a new family, Guntheraninae, to accommodate this genus. He does this on the strength of the accessory dorsal plates, and in particular on the extraordinary habit recorded by Gunther of the attachment of eggs of *G. kallipygos* to the fur of the host (as Womersley, 1952:246 points out, this requires a good deal of further investigation). The present writer is not sure that grounds yet exist for considering the differences to be subfamilial

and prefers not to accept the Guntheraninae. *G. parana* Wom., 1944, listed by Wharton & Fuller (1952:83), is considered by Womersley to be a synonym of the type; Womersley also records *kallipygos* as a *nomen nudum*, the type being *bipygalis*; but a *nomen nudum* has no validity and therefore cannot invalidate a given name.

The species *tindalei* and *translucens* are known only from the adult stage and should therefore be ascribed to this genus tentatively. It will be necessary in future to decide whether nymphs and adults uncorrelated with larvae are more closely related to *Guntherana* or to *Doloisia* (new subgenus)—at present the only character appears to be the more simple sensillae of the former. The ASL/SB ratio of *translucens* is about 1.5.

Old World species (Australasia).—*kallipygos*; ?*tindalei* N, ?*translucens* A (larva of last two unknown).

Genus *Doloisia* Oudemans, 1910, expanded

Type.—*Doloisia synoti* Ouds., 1910:87, *Ent. Ber., Amst.*, 3, 83-90. From a bat, Europe.

Provisional Diagnosis (expanded).—Larval trombiculines of the *Schöngastia* group with 7-segmented legs, a characteristic small scutum with PW much wider than AW, with a tendency to multisetose coxae reaching its highest development in the genotype (all coxae multisetose) but may be only coxae III multisetose (? this character exceptionally absent); palpal claw generally stout and peculiarly curved, usually 3-pronged, but may be 2-pronged; chelicer short, somewhat curved, with a single large recurved dorsal tooth which may be blunt; a tendency to have more than one pair of humeral setae; without long nude setae on legs. Nymphs & Adults (known only for three new species, new subgenus, and for *oculicola*; not known for the typical subgenus) with the general characters of *Euschöngastia* but with a broad sensillary area and short crista (ASL/SB ratio=0.7-1.2, instead of over 1.7) resembling the scutum of *Guntherana*; sensillae conspicuously branched (with spiculate shafts in a new species and *oculicola*, with thickened shaft in another new species undescribed).

Remarks.—The writer knows of only 3 species which resemble the type closely in all characters, namely *D. okabei* Sasa *et al.* 1952 from Japan, *D. brasiliensis* (Fonseca), and *Doloisia* sp.* Varma (in MS) from India. In addition, Radford's species *manipurensis* from India is obviously closely related although coxa I is unisetose. Of the latter species Womersley (1952:204) states his belief that *manipurensis* "might be placed in *Doloisia* Oudemans 1910 as suggested by Fuller, 1948, if that genus can be validly separated from *Schöngastia* when the adults become known" Womersley lays particular stress on the importance of adult characters and doubtless this emphasis is a useful corrective to the development of a classification based almost exclusively on larval characters. The present writer however agrees with a number of other authorities, in recognising that "larval" genera may be perfectly valid. With some new larval and nymphal material to hand it appears that *Doloisia* represents a quite distinct group of considerable complexity.

Subgenus *Doloisia* Oudemans, 1910

Type.—*Doloisia synoti* Ouds. 1910-87, *Ent. Ber. Amst.*, 3, 83-90. From a bat, Europe.

Provisional Diagnosis.—Scutum not heavily chitinised, with posterior margin almost straight or concave; AM seta advanced in front of AL's (so as to make scutum almost triangular or pentagonal), AM and/or AL setae may be nude or almost nude; coxae II and III multisetose, coxa I multisetose or unisetose.

Old World species (Asia).—"HA" n. sp. Varma; *manipurensis* (fig. 3; but see comments below); *okabei*, *synoti*; ? 2 n. spp. from Assam and North Burma (U.S.A. Typhus Commission coll.).

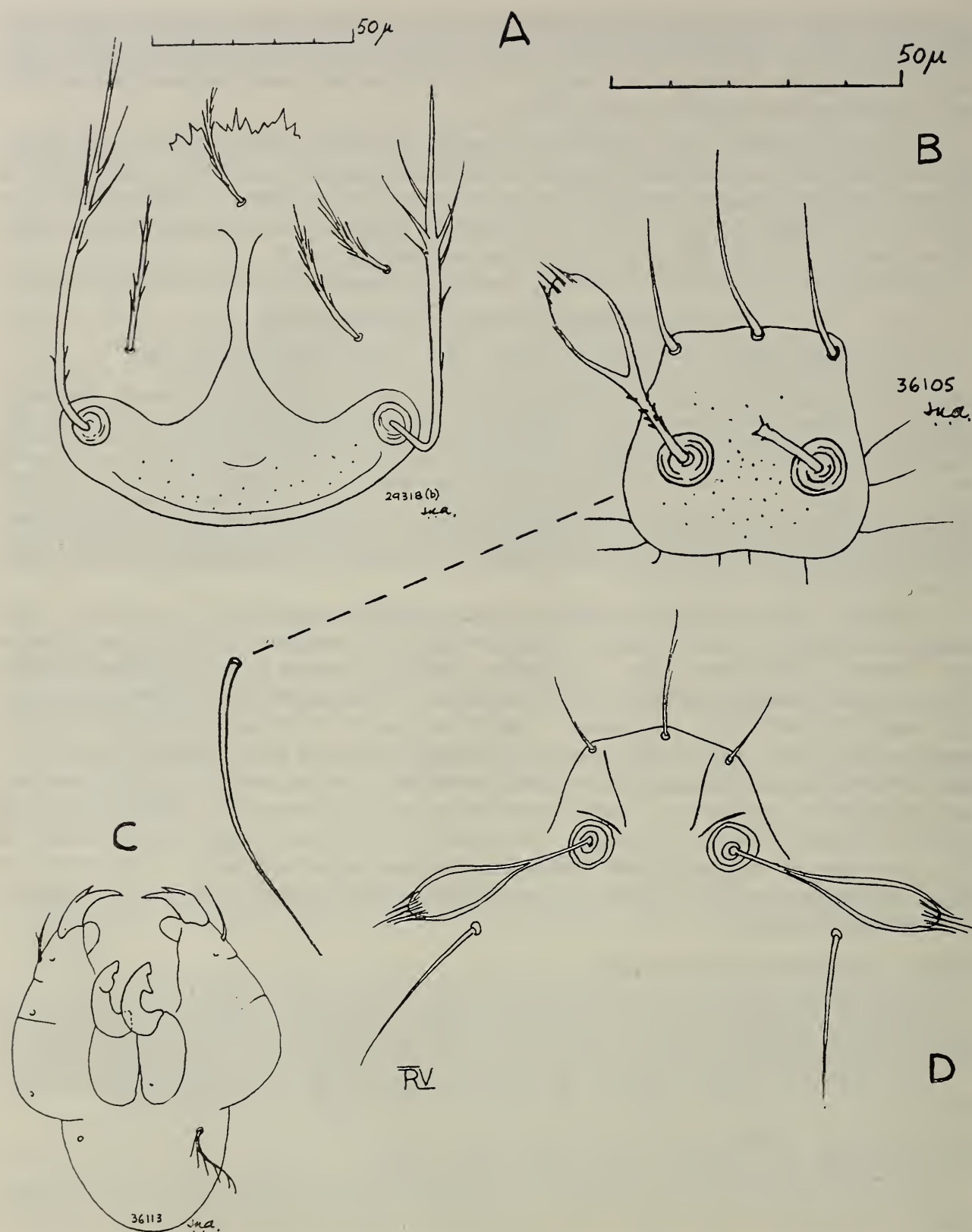
New Subgenus, "VN"-group Audy in MS (figs. 1, 3).

Type.—Malaysian species to be described and designated (Audy in MS).

Provisional Diagnosis.—With small scutum poorly chitinised; PL setae off the scutum and separating widely with engorgement; only coxae II and III multisetose. Nymphs & Adults as described in diagnosis of genus.

Remarks.—We have 4 species from Malaya and one (?two) from North Borneo which have the general characters of *Doloisia* except that the poor chitinisation of the scutum combined

* Since this went to press, Raja Varma has kindly allowed the writer to see his descriptions and illustrations. His new species (here listed as "HA") is close to *manipurensis* and both these species will probably prove to belong to the VN-group which is to be made a new subgenus by the present writer.



3. Characters of *Doloisia* sensu lato

A, scutum of Nymph, species "BL" in VN-group ; for comparison with the closely related species "VN" in fig. 1 on p. 129.

B, Scutum, and C, gnathosome (reduced scale) of species "VA".

D, scutum of *D. manipurensis* (Rad.) drawn by M. G. Raja Varma and reproduced with his kind permission, to same scale as B.

with the apparently slight posterior development seen in the typical group has led to a separation of the PLs from the scutum. Both specimens of the first species seen ("VN") were badly distorted but the resemblance to *manipurensis* was very close indeed, except that no scutal margins could be seen even with phase-contrast microscopy. Nymphs were available and proved sufficiently distinctive (fig. 1) to suggest that the species was generically well defined. A second nymph ("VA" new species, fig. 3) was identified as another *Doloisia* although it had been put aside as *?mutabilis* on account of a multisetose coxa III in the fragmentary larval pelt. A satisfactory description of this larva cannot yet be given. Two other species have recently been collected together (from a different locality, Fraser's Hill), in which the scutal character is obvious. The discovery of these has allowed us to decide that the original species "VN near *manipurensis*" (distorted specimens) also has PLs off the scutum. Mr. Raja Varma, Research Fellow of the Indian Council of Medical Research, has examined type material in the British Museum (Natural History) and has very kindly allowed his drawings of the scutum of *D. manipurensis* to be reproduced here (fig. 3c). Mr. Varma could not see the posterolateral and posterior margins, but this may be extremely difficult in an old mount. Nevertheless, the scutum is very poorly chitinised and the obviously close relationship between *manipurensis* and "VN" n. sp. requires further study—it is possible that *manipurensis* belongs to this new subgenus and not to subg. *Doloisia*, the completion of the indistinct scutum to the PLs in the original description having been due to a misinterpretation. Since this *Study* went to press another new species in this subgenus has been collected from moss forest near Mt. Trus Madi in North Borneo by the third joint Anglo-American expedition in July, 1953. This was a large species occurring within the nasal cavities of rats, a peculiar habitat already explored by P. H. Vercammen-Grandjean in the Belgian Congo (in a private communication Vercammen-Grandjean has commented on, and kindly sent the writer specimens of, new genera and species of intranasal chiggers: the credit for drawing attention to this habitat for chiggers belongs to him). The most significant feature of this new species is the absence of the strong curvature of the palpal claws, which are ordinary in appearance. This point is important when considering the possible relationships of several other species. The nymph, bred by Mr. Nadchatram, is closely similar to the others but the sensillae are more simply barbed. (Note: the intranasal habitat has been described by Wolf and Verc., 1953).

Old World species (Malaysia).—These are to be described in the next *Study* in this series. The species are listed below. It is interesting to note that the first 4 species all came from *Rattus bowersi* from two localities.

1. "VN" n. sp. N., Ulu Langat F.R., Selangor (Nymph, fig. 1).
2. "BL" n. sp. N. One nymph; incomplete larval pelt without scutum, provisionally included in this subgenus. From same host-species and locality as "VN" (Nymph, fig. 3)
3. "VA" n. sp. engorged larvae, from *R. bowersi*: Fraser's Hill, Pahang (fig. 3).
4. "ND" n. sp. engorged larvae, same host species and locality as "VA".
5. "NS" n. sp. engorged larvae, intranasal in rats, Mt. Trus Madi (Ulu Kaingaran), North Borneo; nymphs may shortly be available for study.

New Subgenus: **oculicola**-group **crocidura**-group

Remarks.—The writer is not prepared to give even a provisional diagnosis of this group or these groups without further study. There are probably several species already known which are more closely related to this group than to any other. *S.(S.) oculicola* Wom. (1952:167,383: plates 31, 103) has a small scutum similar to that of typical *Doloisia* except that the posterior margin is medially slightly convex and the SBs relatively somewhat close together. The strong 3-pronged curved palpal claw, the short modified chelicer (blunt denticulations replacing the large blunt tooth) and the additional humeral setae are also collectively important in relating this species to *Doloisia* rather than any species-group of *Euschöngastia*. In addition, the

distinctive nymph resembles those of "VN" and "BL" in shape (ASL/SB ratio about 1.2?) and in the sensillae having sparse long branchlets and spiculate shaft; the long, solitary, paracristal setae are however peculiar. Mr. Womersley is kindly providing material for further study. The peculiar location (conjunctiva) of *oculicola* on the host is interesting in view of the occurrence of "NS" n. sp. on the intranasal mucosa. One of Vercammen's species noted below was also intranasal. It must however be admitted that Vercammen has shown that a number of unrelated species favour this peculiar habitat.

The relationships of at least four other species to this group require study: *E. andrei* (Jadin and Verc., 1952:622), *E. crocidura* (Law. 1949) "DBI-NB" n. sp. Jadin and Verc. (1953 in press) and *E. nausheraensis* (Wom. 1952:202). A specimen of the third was very kindly sent to the writer by Vercammen-Grandjean of the Laboratoire Medicale Province du Kivu, Bukavu (Belgian Congo). It has a small scutum similar in shape to that of *E. andrei*, the 3-pronged palpal claws are characteristically curved terminally, the chelicers have the single large tooth, and coxa III is multisetose. *E. crocidura* is closely similar. This species may link *E. andrei* to the group under discussion. Womersley's species *nausheraensis*, of which the writer has kindly been lent several specimens, has a somewhat different scutum (larger, PW more nearly equal to AW, SBs relatively wide apart) but the posterior border is concave and the scutum generally resembles that of *andrei* (in this, Womersley's figure 52C is slightly inaccurate). There are only 2 humeral setae but coxa III is multisetose. The palpal claw is 2-pronged and not particularly short or incurved, resembling that of "NS" n. sp. from Borneo. Vercammen's species are in a number of features intermediate between *nausheraensis* and *oculicola*, and a good deal of study will be necessary to clarify these interesting relationships. *T. praomyia* Rad. from Africa and *T. jubbulporensis* Wom. have a peculiar scutum like those of *E. andrei* and *E. nausheraensis*: they have been described as *Trombicula* in the absence of sensillae and their true relationships are unknown.

Old World species, relationships sub-judice.—Africa: ?*andrei*, ?*crocidura*, "DBI-NB" Jad. & Verc. ?*dutoiti*. Asia: *nausheraensis*, *oculicola*.

Genus **Riedlinia** Oudemans, 1914

Type.—*Riedlinia coeca* Ouds. 1914:88, *Ent. Ber. Amst.* 4, 84-49. From a bat, hills near Bombay, India.

Diagnosis.—Monotypic: larva with spatulate empodium, claws stronger than usual; eyes absent; scutum roughly pentagonal, with posterior angle, sensillae unknown. Nymphs not known.

Remarks.—Womersley describes this species as having globose sensillae but Fuller (1952:200) in a redescription states that the nature of these organs is unknown. Kalra is attempting to collect topotypic material (personal communication). There is a *lapsus calamae* in Wharton and Fuller where the locality is given as Malaya.

Genus **Endotrombicula** Ewing, 1931

Type.—*Endotrombicula penetrans* Ewing, 1931:16, *Proc. U.S. Nat. Mus.*, 80, 1-19. From amphibian, East Africa.

Diagnosis.—Trombiculines with expanded sensillae, chelicers with large recurved teeth increasing in size proximally; apparently confined to amphibians.

Subgenus **Endotrombicula**, Wharton and Fuller, 1952

Type.—*Endotrombicula penetrans* Ewing, 1931:16. From amphibian, East Africa.

Diagnosis.—*Endotrombicula* whose larvae have a single tarsala I.

Old World species (Africa).—*madagascariensis*; *penetrans*; *pillersi*.

Subgenus **Phrynacarus** Lawrence, 1949, Wharton and Fuller, 1952

Type.—*Phrynacarus fitzsimonsi* Lawrence, 1949:463, *Ann. Natal. Mus.*, 11, 405-486. From amphibian, South Africa.

Diagnosis.—Monotypic; *Endotrombicula* whose larva has several (4) tarsalae I.

Subfamily GAHRLIEPIINAE Womersley

=WALCHIIINAE Ewing

Diagnosis (as in Womersley, 1952:278; as in Wharton and Fuller, 1952:91 but excluding genera *Walchiella* and *Pseudoschöngastia* which are here placed in the Trombiculinae).—Trombiculids whose larvae have no anteromedian or submedian setae on the scutum; scutum frequently extending backwards with or without inclusion of dorsal setae; expanded sensillae; leg I 7-segmented, legs II and III 6-segmented; coxa III frequently with two or more setae; no mastitarsala or mastitibiala III. Nymphs and Adults similar to those of *Guntherana* and *Doloisia* (new subgenus, above), with anterior rod of crista shorter than distance between sensillary bases; sensillae barbed along almost whole length; tarsus I with a subapical dorsal stump-like papilla; tectum rounded or conical, finely denticulate.

Remarks.—Out of a total of 53 larval species known to the writer, at least 20 have been correlated with their nymphs. On the basis of the close similarity between nymphs, Womersley has reduced the four known genera to subgenera of *Gahrlepieia* sens. lat. Previous to this, Womersley and Heaslip (1943:136) had synonymised *Schöngastiella* and *Gateria* with *Gahrlepieia* on larval characters. Gahrlepieine material from Burma, Malaysia, and Africa is being studied in detail by Traub, who is also in favour of recognising the broad genus until further studies clarify matters (Traub and Evans, T. and Morrow). An important contribution is being made by Vercammen who has discovered true gahrlepieine larvae with toothed chelicers in the Belgian Congo and has bred them to the nymph—the nymphs appear to be typical gahrlepieines (Vercammen 1953, and personal communication).

All these and also other workers are aware of the artificial nature of most of the divisions made between the present genera. In effect, these divisions have been made in steps according to the number of setae on the scuta until larvae with many and variable numbers of setae have made further efforts unprofitable; a division has then been made on the marginal or non-marginal placing of the setae on the scutum. The position therefore is that four generic divisions of dubious validity have been reduced to four subgeneric divisions which are still doubtfully valid, pending a revision to be made on the basis of more detailed study of larval and nymphal material. The first step in this revision would be to ignore the existing subgenera completely and to attempt to rearrange the assemblage of known species in natural groups. The following groups suggest themselves to the writer but this grouping is emphatically tentative and its object is simply to stimulate thinking away from the established subgenera. This particular rearrangement is largely based on the scuta, but much more attention should be paid to the chaetotaxy of palps and legs, to distribution of species on hosts and in space. The presence or absence of eyes has been considered of importance but this now appears to be of limited value. The writer himself suspects that more than one valid larval genus will emerge from the temporary repository of the broad genus *Gahrlepieia*, in which case it is possible that the old family name (Walchiinae) may be restored.

(1) **pingue-group**, comprising (A) *pingue*-subgroup, with *brennani*, *enode*, *disparunguis*, *lewthwaitei*, *morobensis*, *pingue*, and (B) *rioi*-subgroup, with *americana*, *rioi*, and n. sp. nr *rioi*. Members of subgroup A show some tendency to a posterior prolongation of the scutum, so that these species might in fact form a series with the *turmalis*-subgroup (below) in which a distinct narrow tongue is developed. Similarly, members of subgroup B may either be grouped with those of A, or they may be taken to form the first of the *bengalensis*-series, in having the posterior margin broader and more evenly rounded (in a new species near *rioi* from Selangor, this margin is very much convex).

(2) **turmalis-ligula-group**, comprising (A) *turmalis*-subgroup (*Walchia*) with *rustica*, *turmalis*, and n. gen. n. sp. Vercammen 1953 (in press), in which there is a distinct prolongation of the scutum to form a narrow tongue, while the chelicers show a tendency to develop a tooth or (in Vercammen's species) teeth. The position of Vercammen's species, including another mentioned below, is complicated by the fact that these two species have been obtained from

an unique locus on the host. The presence of teeth in these two species may be related to a special feeding requirement; it is thus either a convergent development in two different groups or it is a special adaptation of a single group. (B) *ligula*-subgroup (*Schöngastiella*) with *ceylonica*, *kalrata* Traub and Evans 1953 (this *Study* pp. 98, 99), *ligula*, *liota* T. & E., in which the tongue carries an extra pair of posterior setae, presumably derived from the dorsal setae, placed marginally and subterminally.

(3) **bengalensis**-group (*Schöngastiella*) comprising *bengalensis*, *brevis*, *coeca*, *dureni*, *erula*, T. & E., *helata* T. & E., *hipposideros*, *phomunguis*, *gammonsi* T. & E., *kumaonensis*, n. sp. CORU. R17506, plus three atypical members: *arona* T. & E. and *birella* T. & E. (which have the anus borne on a plate and a peculiar arrangement of dorsal setae; see this *Study* pp. 95, 96, 97), and possibly *saduski* (which to the writer appears to be a member of the *bengalensis*-group with a few extra setae on the scutum, variable in number). The possible relation of *G. nanus* to this group is noted below.

(4) **decora**-group (= *Gahrliepia* in part), with *decora*, *insigne*, *ornata*, four related species from Malaysia and Burma with honeycombed scuta, and *cestrata*. Mr M. Nadchatram in studying a series of freshly mounted *G. cestrata*, noted that the punctuation of the scutum was of two kinds, the ordinary small punctae and also a number of large pits which gave a fenestrated appearance to the scutum. These pits or small fenestrae appear to represent the obvious honeycombing which reaches its full development in the other members of this group. It will be noted that this group in fact comprises the subgenus *Gahrliepia*, with the possible exception of *nanus* the genotype, which the writer has not examined. According to Fuller (1952:213), the type has been excessively cleared, so that the detection of unusual punctuation would require a phase-contrast microscope and may no longer be possible. In any case, it would appear that *nanus* may either belong to the *cestrata*-*decora* group, which would then become sufficiently distinctive to be recognised as a genus; or *nanus* may be placed with *saduski*, in the *bengalensis*-group, in which case it might become necessary to synonymise *Schöngastiella* with *Gahrliepia* and raise a new name for the *decora*-group. The coxae III in members of this group are remarkably deep. This character is present to a lesser extent in the *bengalensis*-group but not in the *ligula*-group. Womersley (1952:301) includes *saduski* in the subgenus *Gahrliepia* although some of the setae are not marginal: it is either a *Gateria* or a member of the *bengalensis*-group as noted above.

(5) **fletcheri**-group (= *Gateria*), with *ciliata*, *crocidura*, *fletcheri*, *hirsuta*, *lancearia*, *longipili*, *rutila*, ?*saduski*, *spinulosa*. Fuller (1952:217) notes that *crocidura* and *lancearia* cannot at present be properly distinguished. The relationship between the *bengalensis*-group and the *fletcheri*-group requires careful study: it might be a mistake to draw a line between the two simply on scutal setal counts.

(6) **longiscutullata**-group (*Giroudia* Jad. & Verc.), with two African species *Giroudia longiscutullata* and *G. brennani*. These have the characters of *Gateria* but also have teeth on the chelicers.

Type species.—In view of these uncertainties, the writer prefers not to list and give diagnoses for either the accepted or the tenuously tentative subgenera/genera. A list of the type species is given for reference, and the appended list of Old World species simply follows the accepted classification.

Gahrliepia Oudemans, 1912:273, *Ent. Ber. Amst.*, 3, 272-278. Type *Typhlothrombidium nanus* Ouds., 1910:105, *idem*, 3, 103-109. From a bat, South Africa.

Schöngastiella Hirst, 1915-188, *Bull. ent. Res.*, 6, 183-190. Type *Schöngastiella bengalensis* Hirst, 1915-188, *idem*. From rats, India.

Walchia Ewing, 1931:11, *Proc. U.S. nat. Mus.*, 80, 1-19. Type (*Thrombidium glabrum* Walch, 1927:926, *Geneesk. Tijd. Ned-Ind.* 67, 922-933, homonym, not *Thrombidium glabrum* Duges) = *Walchia pingue* Gater, 1932:173, *Parasitology*, 24, 143-174. From rats, Indo-Malaysia.

Gateria Ewing, 1938:295, *J. Wash. Acad. Sci.*, 28, 288-295. Type *Gahrliepia fletcheri* Gater, 1932:161, *loc. cit.* From rodents & insectivores, Malaya.

Old World species.—Africa: *Schöngastiella coeca*; *Gahrlepieia lawrencei*, *nana*, ? n. sp. CORU 36695 sent by Dr. Lawrence from South Africa; *Giroudia brennani*, *longiscutullata*. *Gateria philipi*, N. g. n. sp. Vercammen, 1953 in press N. Asia &c.: *Walchia brennani* N, *disparunguis* N, *enode* N, *lawrencei* N, *morobensis* N, *ogati*, *pingue* N, *rioi*, n. sp. nr. *rioi*, *rustica* N, *turmalis* N. *Schöngastiella arona* T. & E. N, *bengalensis* N, *birella* T. & E., *brevis*, *ceylonica* N, *erula* T. & E., *gammonsi* T. & E., *helata* T. & E., *hipposideros*, *kalrata* T. & E., *ligula* N, *liota* T. & E., *punctata* N., *SIN* n. sp. (Varma in litt.), n. sp. CORU in MS. *Gahrlepieia cetrata* N, *decora*, *insigne*, *ornata* N, 4 n. spp. in MS. *Gateria romeri*, *rutila* N, *spinulosa*. Also *Sch. wansoni* Wolfs & Verc. 1953 from Africa.

FAMILY LEEUWENHOEKIIDAE WOMERSLEY

OR Subfamilies LEEUWENHOEKIINAE Womersley

and APOLONIINAE Wharton

Provisional Diagnosis of Tentative Family (after Womersley, 1945; Wharton & Fuller 1952:90, 96; Baker & Wharton, 1952; Womersley, 1953, this *Study* p. 108; also Brennan, Wharton, and Womersley, personal communications), for comparison with diagnoses of Trombiculidae & Trombidiidae, pp. 137, 166 Larvae so far known with only one dorsal plate (the scutum) usually carrying an anterior median process (nasus): always with only one pair of sensillae, usually filiform sometimes expanded (when filiform usually nude). Six scutal setae, 2 antero-submedian (except in 2 new genera Wom., 1953), 2 anterolateral, and 2 posterolateral; seta on pedipalpal coxa posterior to base of palpal femur; cheliceral blade frequently modified (toothed, with or without modification of the blade); femora of all legs, or of legs II and III undivided (except in Apoloniinae) and these legs therefore 6-segmented; coxa I 2-setose (except in *Chatia* & *Womersia*), coxa III 1-setose (multisetose in *Chatia*); parasitic on arthropods and vertebrates. Stigmata and tracheae may be present (*Acomatacarus*, *Whartonia*). Nymphs and Adults mostly small (1-2 mm or less), body cordate or pyriform, not constricted (except in *Hannemania*). Scutum with one pair of filamentous sensillae arising from a subposterior sensillary area; scutum ending anteriorly in a triangular tectum usually bearing a pair of setae. Eyes if present 2+2, sessile, away from scutum. Dorsal setae frequently of two kinds.

Remarks.—Few leeuwenhoekiiids have been encountered in India and Malaysia and the present writer is not familiar with the group. He is not prepared to offer any opinions as to the familial or other status of the Leeuwenhoekidae or its components. An attempt is here made to tabulate the known facts and to present a tentative diagnosis of the families Trombiculidae, Leeuwenhoekidae, and Trombidiidae partly for reasons already noted but largely for the writer's own edification.

Most species of this family are known from the larvae. Of the 88 known species (including some of the undescribed species, Womersley in MS, personal communication), 50 are of species of *Acomatacarus* parasitising vertebrates and 16 are species of *Hannemania* from batrachians. Of the ?12 known nymphs and adults 8 are of *Acomatacarus*. The adults so far known are therefore not representative. Womersley is completing a monograph of this family. In the species-lists which follow Wharton & Fuller are followed but the Apoloniinae are provisionally extended after Womersley's revision (1953).

Subfamily LEEUWENHOEKIINAE Womersley

Provisional Diagnosis (Wharton & Fuller, 1952:96, *verbatim*).—"Trombiculids whose larvae have two setae on coxae I, all legs composed of six segments and attenuated sensillae."

Remarks.—Three genera are not represented in the Old World; they are however included in the Table. *Chatia* Brennan in monotypic. Dr. Brennan has very kindly allowed his comments on the nymphs to be quoted (letter of March 1953): they have "no constriction between proterosoma and hysterosoma...pyriform rather than cordate...they have very long legs and are quite similar to *Acomatacarus* nymphs." The nymphs are being described by Lipovsky. *Odontacarus* Ewing, according to Wharton & Fuller (1952:103) is probably a synonym of the subgenus *Acomatacarus*: the specimens in existence are too badly damaged to be studied satisfactorily. *Leeuwenhoekia* Ouds. s. str. is represented by two species from mammals in the Americas: *L. (L.) verduni* (Ouds), and *L. (Comatacarus) americanus* (Ew).

Brennan (1949) and Wharton (1950) have made careful studies of the respiratory organs of chiggers and Wharton & Fuller (1952 : 28) have summarised information up to date. Salivary ducts with taenidia may easily be, and have been, confused with true tracheae in chiggers. A system of unbranched taenidia (opening on a pair of spiracles or stigmata between coxae I and the gnathobase) is apparently truly respiratory and is "characteristic of certain species of the genera *Acomatacarus* and *Whartonia*." The salivary ducts with taenidia have been seen in various genera including *Neoschöngastia*.

Genus *Acomatacarus* Ewing, 1942

Type.—*Acomatacarus arizonensis* Ewing, 1942:490, *J. Parasit.*, 28, 485-493. From reptiles, Mexico and U.S.A.

Diagnosis (Wharton & Fuller, *verbatim*).—"Leeuwenhoekiiids whose larvae have an anterior, median scutal projection, paired submedian scutal setae, and a series of teeth on a relatively modified cheliceral blade" Nymphs & Adults (known only for subgenus *Acomatacarus*) not constricted.

Remarks.—The following list includes the four subgenera represented in the Old World, viz. *Acomatacarus* Ew., *Hyracarus* Law., *Austracarus* Law., and *Austrombicula* Law., without repeating their diagnoses. The writer is grateful to Womersley for information about those species which have been bred to the nymph, and for details of unpublished species.

Old World species.—Europe: *paradoxus*. Africa: *A. (Acom.) gateri*, *geckobius*, *jaegerskioldii*, *lacertae*, *mabuyana*, *namaquensis*, *tenuitarsus*, *thallomyia*, *?theileri*. *A. (Austracarus) procaviae*, *polydiscum*. *A. (Austrombicula) womersleyi*. *A. (Hyr.) typicus*, *lawrencei*, *longipilosus*, *natalensis*. Asia and Pacific: *A. (Acom.) adelaidae*, *athertonensis*, *atollensis*, *attolus* A., *audyi*, *australiensis*, *?barrinensis*, *dromus*, *echidnus*, *?gymnodactyli* (Ew.), *longipes*, *lygosomae*, *mccullochi*, *nova-guinea* N., *patrius* A., *retentus* A., *southcotti*, and over 7 n. spp. (incl. 2 with nymphs) Wom. in MS.; *yosanoi* F. & Ob., 1953.

Genus *Hannemania* Oudemans, 1911

Type.—*Heterothrombidium hylodeus* Oudemans, 1910:88, *Ent. Ber.*, *Amst.*, 3, 83-90. From skin of an amphibian, Brazil.

Diagnosis (from information provided by Wharton).—Leeuwenhoekiiines whose larvae have an anterior medial scutal projection; without stigmata or tracheae, but with well-developed salivary ducts; well-developed teeth disrupting the blade-like conformation of the chelicera; apparently confined to amphibia, penetrating the skin. Nymphs & Adults distinguished by having constricted bodies ("figure-8"). Mostly recorded from the New World.

Remarks.—The nasus to the scutum has been missed in some species (e. g. *H. hylodeus*, *rouxi*—see Fuller 1952 : 239) and as a result this genus has accumulated some species properly belonging to *Whartonia* (q. v.). Ewing (1926) illustrated the constricted nymph of *H. hylae* and Wharton (letter dated April 1953) states that "at least four species of *Hannemania* have been reared and all have the 8-shaped nymphs and adults."

Old World species.—Europe (Sweden): *Hannemania* sp. Sellnick, 1949:129, *Ent. Tidskr.*, 70, 123-135. Pacific (New Caledonia): *rouxi*.

Genus *Whartonia* Ewing, 1944

Type.—*Hannemania nudosetosa* Wharton, 1938:142, *Carn. Inst. Wash. Publ.*, 491, 137-152. From bats, Mexico.

Diagnosis (after Wharton & Fuller, and Wharton in a letter of April, 1953).—Leeuwenhoekiiines whose larvae are without an anteromedian projection (nasus) to the scutum; cheliceral blades modified as a series of recurved teeth; with spiracles (stigmata) and tracheae (cf. *Acomatacarus*): apparently confined to bats. Nymphs and Adults, according to Wharton in correspondence, known for "*Whartonia nudosetosa* and two other species," which have "cordiform nymphs similar to *Acomatacarus*, whose larvae also have spiracles and tracheae."

Remarks.—*Hannemania perplexa* Bren. and the *Hannemania* n. sp. from Malaya noted by Audy (1952) both belong to *Whartonia*. Four species seen by the writer are very large chiggers.

Old World species.—Africa: 2 n. spp. from bats in the Sudan sent by Dr. Thompson to Dr. Zumpt. Asia and Pacific: *vellae*; 1 n. sp. Wom. in MS from Malaya; 2 n. spp. from Borneo.

SUMMARY OF CHIEF CHARACTERS

GENERA AND SUBGENERA OF LEEUWENHOEKIINAE AND APOLONIINAE.

Genus (Subgenus).	Larvae Nymphs Adults known.	LEGS.		SCUTUM.			CHELICERS.	HOSTS.	Remarks.		
		No. segments I:II:III.	Coxal setae I:II:III.	Nasus present.	Setae AM: AL:PL.	Sensillae.					
<i>Leeuwenhoekia</i> Ouds.	...	L	6:6:6	2:1:1	Small ...	2:2:2	filamentous	only usual cap	...	M, America	pentag. scutum; nude setae tib. and tarsus III.
(<i>Leeuwenhoekia</i> Ouds.)	...	L	do.	do.	do.	do.	do.	do.	...	do.	without spiracles and tracheae.
(<i>Comatacarus</i> Ew.)	...	L	do.	do.	do.	do.	do.	simple row	...	M, B, R	pentag. scutum.
<i>Acomatacarus</i> Ew. ...	...	LNA	do.	do.	do.	do.	do.	do.	...	M, B, R	with spiracles and tracheae.
(<i>Acomatacarus</i> Ew.)	...	LNA	do.	do.	do.	do.	do.	do.	...	M, Africa	without sp. and trach.
(<i>Austracarus</i> Law.)	...	L	do.	do.	do.	do.	do.	do.	...	M, Africa	without sp. and trach.
(<i>Austroribicula</i> Law.)	...	L	do.	do.	do.	do.	do.	do.	...	M, Africa	without sp. and trach.
(<i>Hycarus</i> Law.)	...	L	do.	do.	do.	do.	do.	d, v, medial	...	M, R, Africa	with spiracles and tracheae.
(<i>Xenacarus</i> Greenberg)	...	L	do.	do.	do.	do.	do.	nonc	...	M, America	without sp. and trach; without empodium; palpal claws about 7 prongs.
<i>Chatia</i> Bren.	...	LN	do.	2:1:5-7	Absent...	do.	do.	...	...	M, America	
<i>Shunsennia</i>											
Jameson and Toshioka	...	L	do.	2:1:1	Absent...	do.	do.	small subapical,d	...	M, Korea, America	without sp. and trach; empodium present; palpal claw 3-4 pronged.
<i>Hannemania</i> Ouds.	...	LNA	do.	do.	Small ...	do.	do.	blade disrupted	...	Amphibia	without sp. and trach; ? with nude setae tib. and tarsus II; constricted nymphs.
<i>Odontacarus</i> Ew.	...	L	do.	do.	Small ...	1:2:2	do.	simple row	...	M, America	with sp. and trach.
(<i>Whartonia</i> Ew.)	...	LN	do.	do.	Absent ...	2:2:2	do.	recurved	...	Bats	with sp. and trach.
<i>Apollonia</i> Torr. and Brag	...	L	7:7:7	1:1:1	Large ...	2:2:0	do.	none	...	B, America	saliv. ducts +; small scutum.
<i>Sauracarella</i> Law.	...	L	do.	1:1(2):1	Small ...	2:2:2	globose	none	...	R, Africa	saliv. ducts poor.
<i>Womersia</i> Wharton	...	L	do.	1:1:1	Large ...	1:2:0	fil.	none	...	B, America	saliv. ducts +; small scutum.
<i>Womersleyia</i> Rad.	...	L	do.	—	Small ...	2:2:2	do.	none	...	A, Indian atoll	
<i>Grossia</i> Wom.	...	L	do.	2:1:1	Absent...	0:2:2	do. barbed...	d, v, (fine)	...	A, Australia	4-hooked palpal claws, no empodium; peculiar setae base tarsal claw.
<i>Neotrombidium</i> Hirst	...	LA	do.	2:1:2	Large ...	2:2:2	fil.	none	...	Australia; and Bats America.	hooked palpal claws: single tarsal claw.
<i>Nothotrombicula</i> Dumb.	...	L	do.	2:1:1	Medium	1:2:2	fil.	short	...	A, Australia	hooked palpal claws; no empodium.
* <i>Audyana</i> Wom. 1953	...	LN	7:6:6	peglike 2:1:1	Absent...	2:2:2	slender fusiform	2 small subapical hooklike	...	A, Malaya	single tarsal claw, no empodium.
<i>Cockinesia</i> Wom. 1953	...	L	do.	2:1:1	Small ...	do.	do.	none	...	A, Malaya	
<i>Mackerrasiella</i> Wom. 1953	...	L	do.	1:0:1	Medium	do.	do. barbed	none; hooklike	...	A, Australia	no sternal setae.

* The nymph now allows this genus to be placed in the Trombididae, Trombellinae.

Subfamily APOLONIINAE Wharton

Provisional Diagnosis (Wharton, 1947, slightly simplified to include new genera tentatively introduced by Womersley, 1953, this *Study* p. 108).—Leeuwenhoeekiids with 7-segmented legs (except for *Cockingsia*); sensillae expanded or attenuated; mostly parasitising reptiles, birds, and arthropods.

Remarks.—The characters of the new genera and species described by Womersley are included in the Table, but are not discussed further because their full descriptions are included in this *Study*. The type genus is monotypic, *Apolonia tigipioensis* Torres & Braga 1938 being recorded from domestic fowls and also as causing scrub-itch in man. *Womersia* is likewise monotypic, *W. strandtmanni* being from a bird, U.S.A. *Shunsennia* Jameson & Toshioka 1953 is close to *Chatia* but differs in the fewer prongs to the palpal claw and the presence of an empodium. It includes the type *S. tarsalis* (with a tarsala III) and *Hannemania ochotona* Rad.

Since writing this, *Audyana thompsoni* Wom. 1953: 118 has been bred to the nymph, allowing it to be correctly placed in the Trombellinae, family Trombidiidae. Womersley has revised his paper accordingly, but before revision he had noted that all five genera described from larvae taken from arthropods may prove not to be apoloniine.

Old World species.—Africa: *Sauracarella africana*, *montana*, *whartoni* (all from reptiles). Asia and Pacific: *Shunsennia tarsalis* Jam. & Tosh., 1953 from a vole and mouse, Korea. *Cockingsia tenuipes* Wom., 1953 (this *Study* p. 115), from a beetle, Malaya. *Audyana thompsoni* Wom., 1953 (*idem*) from a scorpion, Malaya. *Grossia onychia* Wom., 1953 (*idem*) from a trombidiid, Australia. *Nothotrombicula deinacridae* Dumbleton, 1947 from an orthopteran, New Zealand. *Womersleyia minuta* Rad., 1946 from orthoptera, Maldives Islands, Indian Ocean.

FAMILY TROMBIDIIDAE LEACH

Diagnosis (incomplete, for comparison with that of Leeuwenhoeekiidae).—Larvae usually with more than one dorsal plate: an anterior scutum, frequently deep, dorsal to and obscuring the gnathosome; frequently with a postscutal plate bearing a pair of setae; usually with other dorsal plates bearing setae. Scutal setae usually 6 (anterior, intermediate, and posterior); usually bearing only 1 pair of filiform sensillae. Seta on pedipalpal coxa usually anterior to base of palpal femur. Legs 7-segmented, femora of legs being divided. Sternal setae usually multiple. Parasitic on arthropods, not on vertebrates. Nymphs and Adults often large (1-10mm): body cordate or pyriform broadest between legs II and III. Scutum with 1 (exceptionally 2) pairs sensillae (which may arise off the scutum); extending anteriorly to form an expanded plate which may project over the gnathosome as a tectum, bearing numerous setae (rarely the plate is absent and the scutum undeveloped); eyes if present may be 1+1, 2+2, sessile or pedunculated, placed away from the scutum. Most species of this family are known from the freelifving adult stage and not from the larval stage.

Comments on Checklist of Gunther, 1952

Gunther's checklist (1952) contains valuable references to literature and the location of type material. The early parts of the checklist were completed long before the publication date, as the author explains. It may be helpful to make a few comments as follows—the numbers in brackets refer to Gunther's page-numbers. The subfamily *Hemitrombiculinae* (pp. 2,24) was raised in error, *Hemitrombicula* Ewing being recognised later as a synonym of *Limnochares* Latreille, a hydrachnellid (vide Baker & Wharton, 1952:278). The genus *Nothotrombicula* Dumbleton is unrelated and is now placed provisionally by Womersley in the Apoloniinae sensu lato (Wom., 1953, this *Study* p. 108). As already noted (p. 156 above), the present writer believes it is premature to raise a subfamily Guntheraninae (p. 2) for the genus *Guntherana*, but this is only a matter of opinion. *Guntherana parana* (p. 2) is now synonymised by Womersley with the type *G. kallipygos*. In discussing the genus *Trombicula* (p. 3-4) the author is certainly correct in stating that it will take years to assign species to their subgenera, but this complete suppression of the tentative subgenera is equally certainly not a forward step.

T. mediocris (p.6) is the adult of *T. wichmanni* according to Womersley. Gunther records the breeding of nymphs of *T. hirsti* and the deposition of type and paratype in the South Australian Museum and the School of Public Health and Tropical Medicine in Sydney. Womersley does not however describe the nymph of this important scrub-itch chigger and the matter requires following up. Gunther (p. 5) in discussing the relationships between *hirsti* and *wichmanni* (which some workers would regard as subspecies or varieties) states that he "cannot concede their complete identity and is convinced that they are divisible at least into distinct subgenera. This will be discussed in (his) Part VI; meanwhile (he) is listing them as distinct species." The discussion referred to (p. 8) is a statement of opinion, expressed in a peculiar double negative which does not accord with the author's suppression of subgenera. No reasons are

given and the author's intention is not clear. On the same page he lists *hakei* which Womersley describes as a form of *hirsti*, not of *wichmanni*. *T. pseudoakamushi* (p. 12) is a synonym of *T. wichmanni*.

T. obscura (p. 15) has since been identified with *T. akamushi* by Womersley. As noted by Traub & Audy (1953, this *Study* p. 74) a form which appears to be very close to *obscura* is the dominant form of *akamushi* in North Borneo, where it occurs together with *deliensis*. Nymphs have been bred and an opinion on this form awaits further study. *T. keukenschrijveri* (p. 17) can be confirmed as a *Trombicula* (*Leptotrombidium*) in the *akamushi*-group. *T. hastata* (p. 18) is placed by the present writer in the subgenus *Trombiculindus*. On p. 21 line 20 *deliensis* is a *lapsus calamae* presumably for *mediocris*. Of the adults listed on pp. 21-22, *T. signata* is not a trombiculid but a *Podothrombidium* (vide Wom., 1952:312; it is also listed by Wharton & Fuller, 1952:70); *tindalei* and *translucens* are now placed in *Guntherana* (see p. 157 above). *T. chiroptera* (p. 22) is a synonym of *quadriense*. Of species listed under *Schöngastia* on p. 25, Womersley has identified both *katonis* and *pusilla* with *schuffneri*, while he omits all mention of *jamesi* (= *rotunda*, nom. nud.).

In dealing (p. 26) with the confusion of *Eu*—, *Neo*—, *Para*—, and *Ascoschöngastia*, the author states that he is taking the bull by the horns, but he is thrown in the wrong direction in his choice of *Neoschöngastia* which is the best-defined group and is therefore least suited to serve as a taxonomic dustbin. *Trisetica* (p. 37) is noted as fairly obviously a synonym of *Tecomatlana* but the authors of *Trisetica* have carefully discussed this very point. In connexion with the discussion of leeuwenhoekids on p. 38, the reader may be referred to Womersley, 1953 (this *Study* p. 108). The Walchiinae (Gahrlepiinae), p. 43-48, are in a fluid state and have already been discussed above.

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SUMMARY

1. The results of a preliminary study of some 130 species of trombiculid larvae and 70 species of nymphs from Malaysia are recorded. The conclusions are provisional but are made available to fellow-taxonomists because it will be many years before the available material can be fully studied and described. This paper is intended to be an appendix to the monographs by Womersley (1952) and Wharton and Fuller (1952).

2. The taxonomic importance is discussed of various characters, as listed in the Contents, and attention is drawn to certain characters which have been neglected. A possible course of evolution is given of similar species with different seasonal behaviour occurring together in the same country. The humeral, dorsal, caudal and ventral, and the various scutal, setae are believed to be influenced by different embryonic developmental fields, so that their differences are probably of more taxonomic importance than is usually supposed.

3. The classification of the trombiculids, at present based largely on the larval stage, will ultimately be based on postlarval as well as larval characters. Womersley's important study of the postlarval stages is a pioneer work; much still remains to be done. Our understanding of the taxonomic characters of the postlarval stages is considered to be still too undeveloped to allow stabilisation.

4. In the light of the Malaysian material, revised diagnoses (many of which are provisional) are given of the genera and subgenera of Old World chiggers, together with lists of those species from Europe, Africa, and the Asiatic-Pacific area which have been described by early 1953.

5. In addition to the accepted genera and subgenera, over 30 species groups are listed, at least three of which may deserve recognition as subgenera (viz. the *Euschöngastia indica*, *E. lacunosa*, and *Doloisia oculicola* groups).

6. The Trombiculinae are divided into two generic groups, related respectively to *Trombicula* and to *Euschöngastia*. The latter group has many affinities with the Gahrlepiinae (Walchiinae). The genera *Walchiella* (here treated as a subgenus of *Euschöngastia*, close to the *lacunosa*-group) and *Pseudoschöngastia* are considered to belong properly to the *Euschöngastia* complex and not to the Gahrlepiines.

7. The genus *Trombicula* sensu lato is revised and the subgenus *Trombicula* is based on the larval and nymphal characters of a new, undescribed bat-chigger which appears to be congeneric, if not identical, with the genotype *T. minor*. Evidence is offered to show that the postlarval stages of *T. minor* lack eyes. The subgenus *Leptotrombidium* is provisionally revised sensu lato; over 60 species are at present allocated to it.

8. *Fonsecia* is restored to generic rank and it is considered that the *T. ilei* group, which does not have modified scutal setae, may prove to be congeneric with it.

9. The genus *Euschöngastia* sensu lato is provisionally considered to comprise the subgenera *Euschöngastia*, *Walchiella*, and *Helenicula* n. subgen., together with the *indica*-group and the *lacunosa*-group which appear to be at least of subgeneric status but the limits of which cannot yet be defined. The *lacunosa*-group may possibly be identified with *Walchiella*, while the *indica*-group has close affinities with *Doloisia* sensu lato.

10. The genus *Doloisia* is treated sensu lato, comprising (a) the subgenus *Doloisia* sensu stricto, (b) a new subgenus (to be published), the larvae of which have PL setae off the scutum and the nymphs of which are very distinctive, resembling those of *Guntherana* and the Gahrlepiines in the shape of the scutum, and (c) an *oculicola*-complex which requires much further study. The larvae of *Doloisia* appear to have affinities with members of the *E. indica* group, and this requires further study.

11. The Gahrlepiinae (Walchiinae) are treated sensu stricto because they are a very distinctive group in both larvae and nymphs. The broad genus *Gahrlepieia* is considered to be the temporary repository of two or more groups which will later be given generic status. It is considered that the existing subgenera are based on false distinctions and that the subfamily needs drastic revision.

12. The Leeuwenhoekinae and Apoloniinae are hardly represented in the Indo-Malaysian collections, with the exception of *Whartonia* on bats. These subfamilies are briefly considered. Larval characters of the various genera are tabulated: Womersley's new genera, based on chiggers from arthropods and provisionally placed by him in the Apoloniinae, are included in the tabulation.

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MALAYSIAN PARASITES X
FEEDING TIMES OF TROMBICULID LARVAE

By

J. L. HARRISON

Mites of the family Trombiculidae are, for most of their lives, free-living predators in the surface layer of the soil. Once in their lifetime, however, they are parasitic, for the newly hatched larva, or "chigger", climbs onto a larger animal, attaches, and spends some day sucking the lysed tissues of the host. When it is engorged it drops off again and spends the rest of its life as a non-parasitic soil mite. While there is evidence that a chigger which has not been able to engorge may attach to a second host (e.g., Mackie *et al.* 1946, p. 213), the fact that engorged larvae will readily transform into nymphs (which are never known to be parasitic) argues that normally the mite feeds parasitically only once in its lifetime. The host varies with the species of mite, and with the opportunity for infestation, but may be a mammal, a bird, a reptile, or more rarely an amphibian or an arthropod. For any one species of mite there is usually one host, or one group of hosts, which is clearly the principal support of the species, but the range of possible hosts is often very wide.

Mite populations

A convenient measure of the population of mites may thus be obtained from the infestation rate of a principal host. For any one species of mite in any one kind of habitat a direct comparison of infestation rates is probably valid as a comparison of the populations, and thus infestation rates alone may be used to compare the effects of such variables as weather, soil, acaricides, and burning.

When different species of mites are involved, however, such comparisons are no longer valid, for different species spend different times attached to the host, and this must be taken into account. Thus if chigger *A* has a feeding time twice as long as that of *B*, then a certain population of chigger *A* will produce twice the average infestation of its host as will the same population of chigger *B*. The average number of fresh attachments daily will be the same for each species, but since *A* feeds for twice as long, the average number of *A* present at any one time (which infestation rate measures) will be twice that of *B*.

A convenient measure, which takes this into account, is the "turnover" of chiggers, that is the number of chiggers attaching (or detaching) in unit time. It may be estimated by dividing the infestation rate by the mean feeding time. For example a mean infestation of 100 chiggers per rat, mean feeding time 3 days, represents a *turnover* of:

$$\frac{100}{3} = 33.3 \text{ chiggers per rat per day}$$

OR

$$\frac{100}{0.1} = 1,000 \text{ chiggers per rat per month (since 3 days} = 1/10 \text{th of a 30 day month).}$$

If the rat population is known (and it is now possible to give reasonably good estimates) the chigger population can be expressed as a turnover of so many chiggers per hectare per month. If the mean length of life of the mite is known this may be further expressed as an actual density of mites at any one time.

It will be seen that the statistic needed is the mean duration of the time spent by the chigger on the host, and it is in this sense that the expression "feeding time" is used here. Since the chigger might take some time to settle down to its meal, this "feeding time" will be slightly

longer than the actual period of attachment and feeding, but the discrepancy is likely to be less than the error of estimation, and is, therefore, of little practical importance.

Some efforts were made by the Scrub Typhus Research Laboratory at Imphal, India, to estimate the feeding-times of the local chiggers and thus to gain some idea of their relative turnovers (Audy, 1947). The only interval observed was the time taken for the detachment of the bulk of chiggers attached to freshly caught wild rats, on which the mites had already been feeding for unknown periods; but in the case of the vector *Trombicula deliensis*, experimentally infested rats were observed. Rough estimates were obtained and presented with a note that the data required checking by more careful and continued observations. The present paper describes experiments involving such observations on species prevalent in Malaya, while also presenting a statistical method of dealing with data obtained from wild-caught hosts.

Materials and Methods

A number of methods of estimating the feeding time are available, but in the present paper only those methods are considered which involve timing the mites feeding on captive animals, and the hosts used have mostly been rats.

The host from which chiggers are to be recovered is kept in a small cage over an enamelled iron tray filled with water. The cage is supported on legs which stand in the water, and chiggers which detach fall through the mesh of the floor onto the water surface where they float. Faeces and other debris fall into the water and sink. The trays are examined from time to time, all floating chiggers are picked off the surface, and the trays are cleaned. Chiggers are either mounted immediately for identification or they are kept in watch-glasses of water, where they remain on the surface until they moult, when the cast skin can be mounted and identified as readily as the larva itself. The nymph may be used for taxonomic studies, or for breeding.

In this way feeding times have been measured on chiggers from three sources:

1. from the natural infestation of trapped wild rats and other animals.
2. from the natural infestation of rats during mark-and-recapture experiments.
3. from the feeding of laboratory-bred mites on immobilised white mice.

Wild rats trapped alive during the ordinary routine of collecting normally bear chiggers. Such rats are often kept until the chiggers detach themselves, thus providing both a measure of apparent feeding time and engorged chiggers for breeding. Since there is no way of knowing how long the chiggers have been on the rat before it was trapped, the interpretation of these figures presents special difficulties which are discussed below.

In the mark-recapture experiments on rats, the rats are trapped, marked, and released again at the point of capture, to be recaptured again from time to time. At each capture the rat is lightly anaesthetised and any chiggers present are removed under a binocular dissecting microscope. The standard of efficiency of the removal is sufficient to assure that practically all mites are so removed. Sometimes a rat is recaptured within 24 hours of release, and often such rats bear mites which must have climbed onto the rat during its short period of freedom. Such rats are kept until the mites detach naturally so that their feeding time may be measured directly.

The recapture of an infested rat within 24 hours is, however, comparatively rare, and therefore, to increase the number of available observations, rats recaptured within 48 hours of release and found infested are treated in the same way.

Chiggers bred in the laboratory are fed by dropping them onto the head of an anaesthetised white mouse, which is then imprisoned in a small cage over a tray of water in such a way that it cannot scratch its ears (where the chiggers attach). In this way the feeding time can be measured fairly accurately, but the drawbacks are that the host and the conditions of attachment

are unusual, and that it is impracticable to keep the mouse in such a constrained position for very long so chiggers with unusually long feeding times are not recorded.

For the wild mites records are kept on punch-cards, one for each rat (or occasion, for mark-release rats) showing the species of rat, the species of mite recovered, the register number of the rat, date and locality trapped, and its exposure to infestation (e.g., one-day, two-day, unknown). For each day after capture of the rat is shown the number of mites recovered, by species. Normal procedure would be for a rat to be trapped during the night. The trap with its encaged rat would be brought to the laboratory during the morning and set up in a cage over a water tray at sometime between 9 a.m. and mid-day. The tray would then be examined daily between 9 a.m. and 11 a.m. The "day" for which a mite is recorded as detaching is thus a 24 hour period from about 10 a.m. to 10 a.m., with zero on the morning after the rat was trapped.

Interpretation of results

For laboratory bred chiggers, put onto a mouse at a known time, results are straightforward. The validity of applying them to field conditions however is doubtful, for several reasons. The chiggers are put onto the head of a mouse during the day, whereas in nature they would climb onto some lower part of the body probably during the night and make their way to the ears. Again, although mice are convenient laboratory animals for studying infections transmitted by the chiggers, they are not readily acceptable as hosts for the mites (Cockings 1948, Harrison and Audy, 1951) a factor which may or may not affect the feeding time.

Mark-recapture experiments

Marked rats are normally released at the point of capture when the traps are visited in the morning but sometimes they are released in the evening. Rats are nocturnal, and in our experience mites are active only when the dew is on the ground, that is to say that they will have gone into hiding by 9 a.m. and will not become active until after sunset. Whether the rat is released in the morning or in the evening, therefore, it is unlikely to pick up any mites before sunset (about 7 p.m.). The rats are likely to be trapped in the earlier part of the night after which their chances of picking up mites are considerably reduced judging from the results of setting out rats in cages as bait. It seems fair, therefore, to allow that a chigger on a rat trapped within 24 hours of release has been picked up during the first half of the night, say between 7 p.m. and 1 a.m., central time 10 p.m.

If the recaptured rat is set over water at about 10 a.m. the next morning, the first day for mite recovery will extend from 10 a.m. on day zero to 10 a.m. on day one, with a central time of 10 p.m. Mites found in the tray on day 1 may, therefore, fairly be counted as having fed for a period grouped about one day, and the best estimate of the mean feeding time will be obtained by treating the numbers recovered on days 1,2,3, etc., as the numbers feeding for periods of central values 1,2,3, etc., days.

In fact it appears that most of the chiggers leave the rat during the night or early morning. Table 1 shows the result of examining trays at 8 a.m., 12 noon, and 4 p.m., for the two mites *T. akamushi* and *T. deliensis* on two host species. The total number of mites recovered at each of these times is shown compared with the number "expected" if the mites came off irrespective of time. The 8 a.m. count represents a sixteen hour collecting period, and the 12 noon and 4 p.m. counts represent four-hour periods each, and therefore the numbers would be expected to be in the ratio of 4: 1: 1. In fact there is a great excess of mites in the 8 a.m. count, showing that most mites must detach during the night or early morning. The fact that the 12 noon count is consistently greater than the 4 p.m. count suggests either that the mites may spend some time wandering about on their host before dropping off, or that the modal time of detachment is in the morning, nearer to 8 a.m. than 4 p.m.

TABLE I

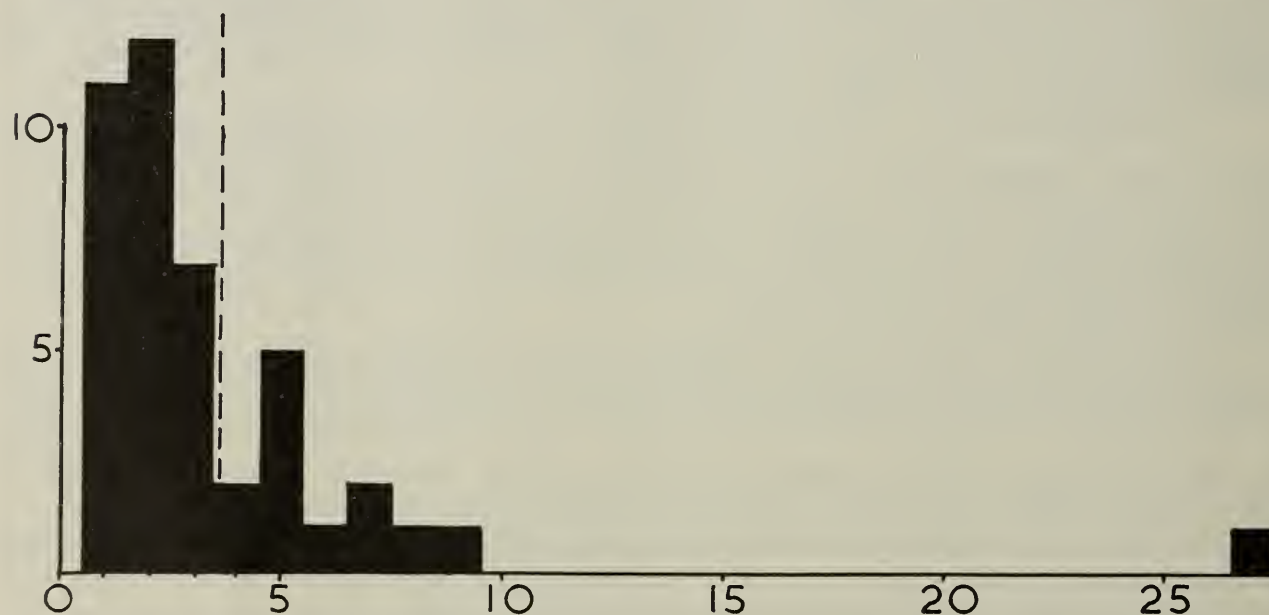
TIMES AT WHICH CHIGGERS DETACH

For *Trombicula akamushi* and *T. deliensis* on *Rattus rattus jalorensis* and *R. r. argentiventer* only, is shown the total numbers of chiggers found at the 8 a.m., 12 noon, and 4 p.m. counts. For comparison the numbers in italics are that part of the total proportional to the time interval (i.e. the "expected" number if the mites detached at random). The observed and expected numbers are compared by a chi-squared test, giving the probability that the difference is due to chance.

Mite	Rat	No. of rats	Gross number of mites at:			chi ²	Probability
			8 a.m.	12 noon	4 p.m.		
<i>T. aka.</i>	... <i>R.r.a.</i>	13 obs.	1,916	291	199	190	less than 0.001
		exp.	1,604	401	401		
<i>T. aka.</i>	... <i>R.r.j.</i>	10 obs.	348	108	16	64	less than 0.001
		exp.	314	79	79		
<i>T. del.</i>	... <i>R.r.a.</i>	9 obs.	62	10	2	12	0.002
		exp.	49	12	12		
<i>T. del.</i>	... <i>R.r.j.</i>	16 obs.	551	54	40	100	less than 0.001
		exp.	431	107	107		

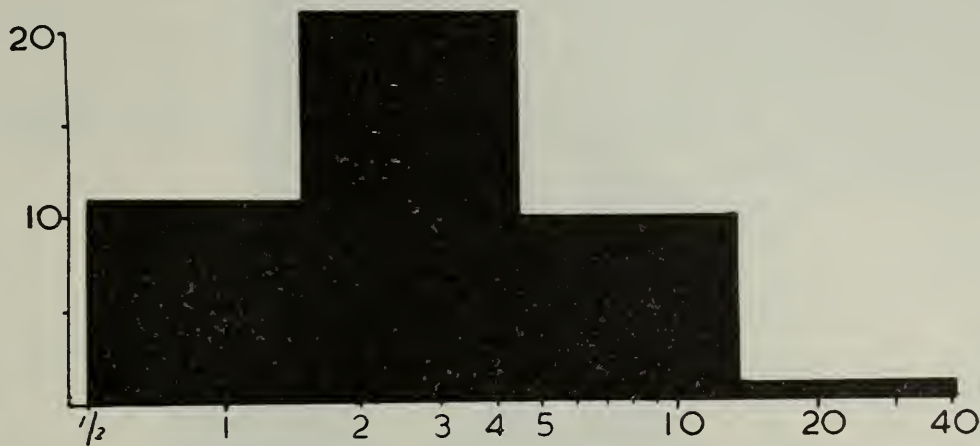
If we accept these mites as typical, therefore, we must consider the feeding times not as a continuous distribution, but as tending towards a discrete series at one day intervals.

Fig 1 shows the sort of result obtained. It shows the total numbers of *Trombicula deliensis* recovered from thirteen rats for each day after trapping. Forty-two of the forty-three feeding times are closely grouped about the mean of 3.56 (standard deviation 4.2, standard error of the mean 0.65) with a modal group of 2 days, and a maximum of 9 days. The forty third chigger was recorded as feeding for 27 days, a deviation which, were the distribution normal, would be



1. Recoveries of *Trombicula deliensis* from 13 rats exposed for one day. Heights of columns=numbers of chiggers recovered each day after retrapping the rat. Broken line=arithmetic mean.

expected only about once in a hundred million times. The distribution however is clearly skew, and if the data are replotted on a logarithmic scale of time (Fig. 2) the histogram approximates to a normal distribution.



2. Recoveries of *T. deliensis* on a logarithmic scale of days. The same data as Fig. 1, but time scale logarithmic so that each interval represents three times as many days as the preceding.

The extreme value now falls into place as an unusual variant to be expected once in three or four hundred times.

There is the possibility that such an extreme value may be caused by the chigger dying while attached and being finally dislodged by the scratching of the rat. While such a possibility is freely admitted (there is no record of whether the mite was alive when recovered) the value should, strictly, be taken into account in calculating the "mean feeding time" as defined above, since it would undoubtedly be counted in calculating the infestation rate. If the extreme value is ignored the statistics become: mean 3.0, Sd. 1.93, se. 0.30.

The most useful statistics would seem to be the arithmetic mean, which is needed for population calculations, and the mode and the range, to illustrate the feeding habits. Since each group is closely centered the mode is taken as the central value of the modal group. In none of the distributions obtained is it possible to estimate any lower limit of feeding time and therefore only the upper limit is estimated. The upper limit is liable to large random variations, as in the example above, and it seems better to take the value within which 95 per cent. of the observations lie, corresponding to a value of the mean plus twice the standard deviation in a normal distribution. In the example given above the observed 95 per cent. range (within which 41 of the observations lie) is up to eight days. Taking the adjusted value of the mean (3.0) and standard deviation (1.93) the expected value would be 6.86 days.

Two-day exposures

Rats recovered within 48 hours of release have been exposed to a similar risk of infestation for two successive nights. There is no reason to suppose that actual infestation on one night is likely to affect the probability of infestation on the following night (although the probabilities for the two nights will be correlated), so that on the average the two probabilities should be the same. That this is so is shown in Table 2, from which it is clear that the probability of remaining uninfested for two nights is very close to the square of the probability of remaining uninfested for one night. The smaller number of recaptures after two nights is due to the method of trapping at one site for about five nights at a time.

TABLE 2

INFESTATION OF MARKED RATS CAPTURED AFTER ONE AND TWO DAYS FREEDOM

For each species, or group of species, are shown the numbers infested and not infested with chiggers of any kind, and the proportion not infested. For comparison the "expected" numbers and proportion are shown in italics. The "expected" proportion is, for the one-day rats the square root of the observed proportion of the two-day rats, and for the two-day rats the square of the observed proportion of one-day rats. The numbers are compared by a chi-square test the result of which is shown together with the probability of getting such a value of chi-squared by chance,

Species of rat	One day exposure.			Two day exposure.			chi ²	P
	Inf.	Not inf.	Proportion not inf.	Inf.	Not inf.	Proportion not inf.		
<i>R. exulans</i> ...	11 <i>17.5</i>	62 <i>55.5</i>	.85 <i>.76</i>	20 <i>13</i>	27 <i>34</i>	.57 <i>.72</i>	...	8.4 ...
<i>R. r. jalorensis</i> ...	20 <i>15</i>	37 <i>42</i>	.65 <i>.73</i>	21 <i>26.5</i>	25 <i>19.5</i>	.54 <i>.42</i>	...	4.9 ...
<i>R. whiteheadi</i> ...	3 <i>3.5</i>	16 <i>15.5</i>	.84 <i>.82</i>	3 <i>2.6</i>	6 <i>6.4</i>	.67 <i>.71</i>	...	0.17 ...
Others (<i>R. r. argentiventer</i> , <i>R. rajah</i> , <i>mülleri</i> and <i>sabanus</i>) ...	13 <i>12</i>	38 <i>39</i>	.74 <i>.76</i>	12 <i>12.5</i>	16 <i>15.5</i>	.57 <i>.55</i>	...	0.15 ...

The central value of the expected infestation during two nights may, therefore, fairly be taken as midway between the values for the separate nights, i.e., at about 10 a.m. on the day before being brought in. The best estimate of the mean feeding time is thus the mean of the observed times plus half a day. The mode is estimated by dividing the modal group in proportion to the adjoining groups and adding half a day. The 95 per cent. range is taken as above.

Wild rats

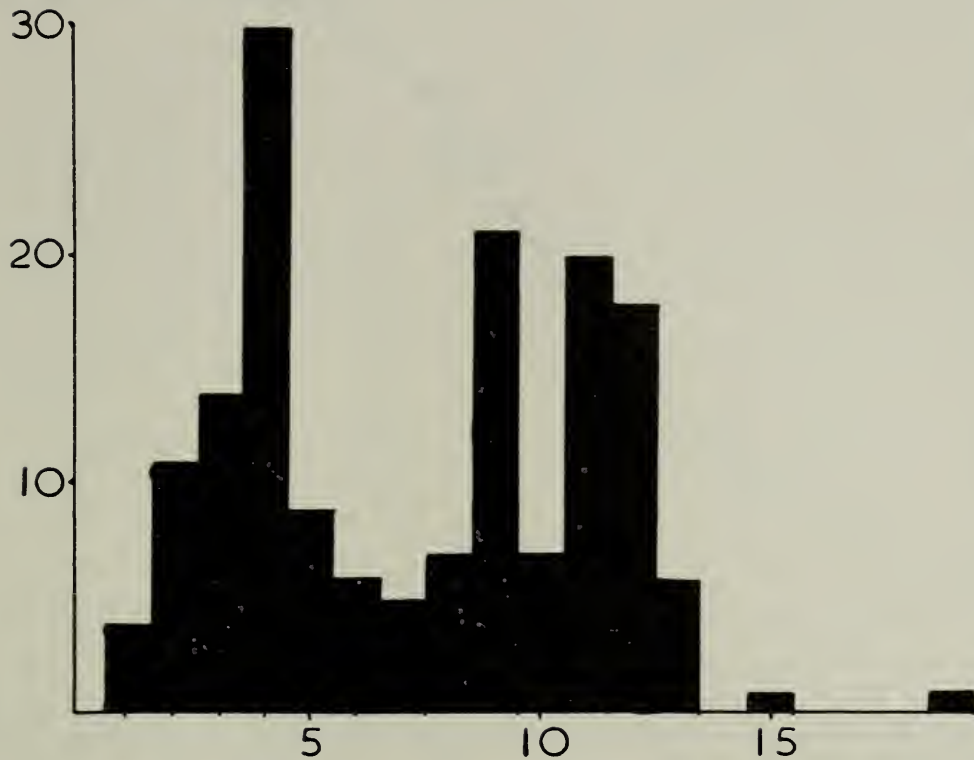
Unmarked rats of unknown exposure presumably bear a mixture of the remains of successive infestations spread over as many days as the maximum feeding time of the chiggers concerned. Two methods of estimating the true feeding time have been used.

1. *The average mode*.—Fig. 3 shows a histogram of the apparent feeding times of chiggers of the species *E. (Walchiella) oudemansi* from a wild caught specimen of *Rattus bowersi*. Evidently this is not an example of random distribution about a mean, but of distribution about two modes at days 4 and 11, or possibly three at 4, 9, and 11. Presumably the population of mites on the rat represents two or three separate attacks and the peaks in the distribution represents the modes of times of the attacks.

If a sufficient number of examples were taken presumably all possible apparent modal feeding times would be represented, from zero to the actual modal time, in equal abundance. The mean of all such modal values, therefore, should be equal to half the true mode.

In practice a "mode" has been scored for each peak which is at least three mites greater than the values before and after. Day one has been counted as a mode when the score was three greater than on day two. The mean of all these modal values has been calculated and doubled to give an estimate of the true mode.

A rough estimate of the maximum has been made by adding the mean of the observed maxima rat by rat, to the mean of the modal values (i.e. half the estimated mode). The reason for this is that only rats bearing a reasonable number of mites were kept over water.



3. Numbers of *Euschöngastia (Walchiella) oudemansi* recovered day by day from a single wild-caught rat.

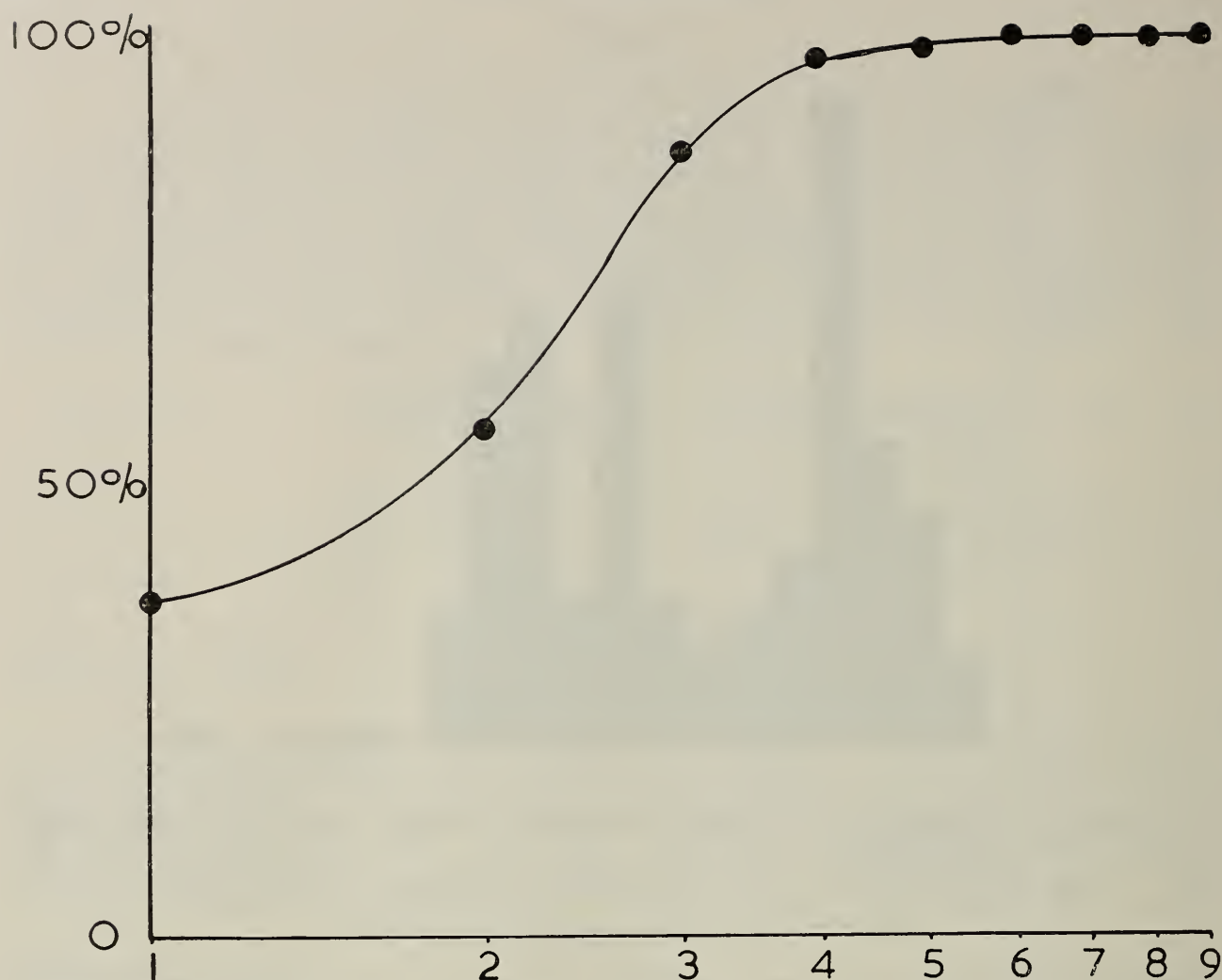
The chiggers clearly detach about two or three modal times. These probably represent two or three separate mass infestations.

It seems fair to assume that any rat so qualifying had not yet lost the modal group of its last infestation. The maxima therefore should range from the value by which the maximum exceeds the mode to the true maximum, and the mean value of all maxima should approximate to the true maximum less half the mode.

2. *Angular transformation*.—If all apparent feeding times for any one species of mite are summed a sigmoidal curve is obtained, such as that shown in fig. 4 in which the total numbers of *Trombicula deliensis*, from twenty-four wild-caught rats, which had been recovered by any one day are shown as a percentage of the total number recovered, on a logarithmic scale of time. If the number of mites attacking a population of rats each day is approximately constant, then the population of mites on the rats will clearly settle down to some constant number, N say, from which a constant number, n say, leaves daily, and to which the same number, n , is added daily. The mean feeding time is clearly $\frac{N}{n}$ which is the inverse of $\frac{n}{N}$ the proportion leaving daily.

If the whole population of rats is now trapped the number of mites leaving daily should be n , but since the mite population is not replenished this number gets less as time goes on. The problem of estimating the mean feeding time can therefore be resolved into one of estimating the proportion of mites on a population of rats which come off the rats during the first day after trapping. The inverse of this is the mean feeding time.

From data of the sort shown in fig. 4 this number could be estimated by fitting a curve to the points and seeing where it cuts the vertical equivalent to day one. The curve however



4. Proportion of all *T. deliensis* from wild-caught rats recovered by the time shown.

The time scale is logarithmic.

is not an easy one to fit, and the problem is made much easier if the percentages are transformed into angles according to the relation,

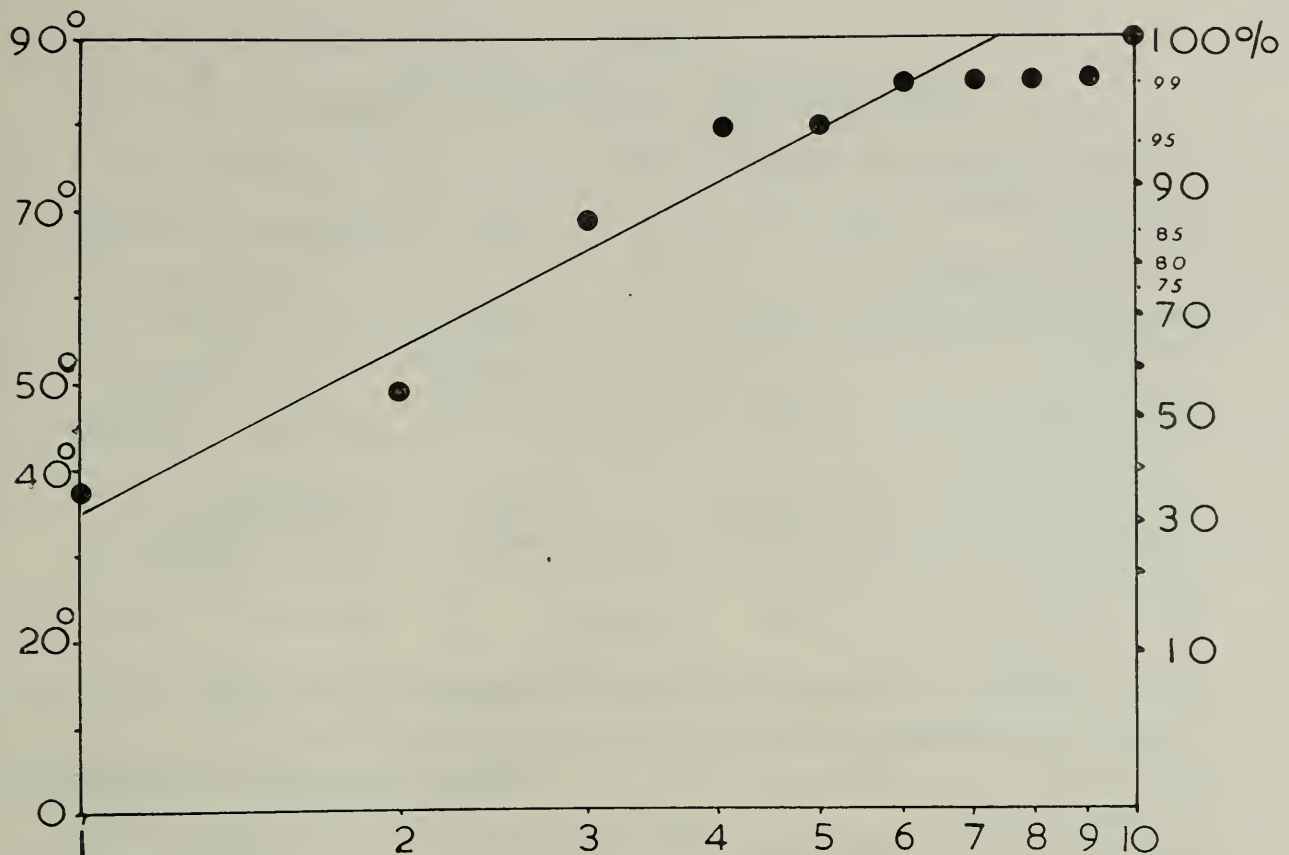
$$p = \sin^2 \theta,$$

when the sigmoidal curve will approximate to a straight line. Values of the angles are tabulated by Fisher and Yates (1942) and in practice percentages are converted to angles from the table, plotted on logarithmic paper, and a straight line drawn through the points by eye. Where this cuts the axis for day one gives the angle and hence the percentage for day one. The inverse of this is an estimate of the mean feeding time. Where the line reaches 90° , corresponding to 100 per cent., gives an estimate of the maximum feeding time. The data from Fig. 4 is shown plotted in this way in Fig. 5.

Results

Measurements are accumulating slowly for a large number of species at once. Some of the estimates are reasonably good, many are very rough indeed; but even a rough estimate is better than none at all, so all available information is presented here. Results are given in detail by methods of estimation in the lists below and are summarised in table 3.

In the list, species of mites are given in the order of the *Preliminary Checklist of Malaysian Trombiculid mites* (Rep. Inst. med. Res., 1951), but some of the names have been revised to



5. Angles of proportions of *T. deliensis*.

The percentages shown in Fig. 4 and on the right of the diagram have been transformed to angles in order to straighten the sigmoidal curve of Fig. 4.

conform with current nomenclature. For each species the statistics are shown separately for each source, and the numbers of mites and hosts on which they are based is indicated. Thus "1 day (43/13)" signifies that from "1 day rats" forty-three mites from thirteen rats were timed. Hosts for laboratory bred mites are white mice, for other mites rats of the genus *Rattus* unless otherwise indicated. The rat hosts of any one mite usually comprise several of the following species:

<i>Rattus rattus argentiventer</i>	<i>R. mülleri</i>
<i>R. r. diardii</i>	<i>R. bowersi</i>
<i>R. r. jalorensis</i>	<i>R. sabanus</i>
<i>R. exulans</i>	<i>R. rajah</i> (including <i>R. surifer</i>)

The hosts of *Trombicula rara* were skinks (lizards) of the species *Mabuya multifasciata*.

Abbreviations used in List 1

Laboratory: information obtained from laboratory breeding of mites

1 day: from marked rats captured within one day of release

2 day: from marked rats captured within two days of release

Wild: from unmarked rats (mean estimated from angular transformation, mode from mean mode, range from both)

Mn: Arithmetic mean (+ standard error for "1 day" timings)

md: Mode

rg: Range (upper limit only)

rg, 95% time group within which 95% of the chiggers have fed

rg, *m.m* maximum estimated from mean mode

rg, 100% maximum estimated from angular transformation

LIST I

Chiggers for which extensive data are available

4. *Trombicula (Eutrombicula) wichmanni* (Ouds.):
2 day (1/1) 5 days
Wild (27/12) ... $Mn=3...$... $md=4$... $rg,mm=4$... $100\%=4$
6. *T. akamushi* (Brumpt)
Laboratory (2,665/31) $Mn=2.1+0.1$... $md=2$... $rg,95\%=4$
1 day (78/11) ... $2.8+0.2$... 3 ... 5
2 day (82/4)... ... 3.2 ... 3.6 ... 4
Wild (3,636/30) ... 2.4 ... 4.4 $rg,mm=6$... $100\%=5$
7. *T. deliensis* (Walch)
Laboratory (723/19) $Mn=3.4+0.1$... $md=3$... $rg,95\%=6$
1 day (43/13) ... $Mn=3.0(3.6^*)+0.3$... $md=2$... $rg,95\%=7(9^*)$
2 day (19/4)... ... 2.8 ... 3 ... 3
Wild (649/35) ... 2.9 ... 4 ... $rg,mm=6$... $199\%=8$
- 13A. *T. sp. nr. bodensis*
Wild (625/12) ... $Mn=7$... $md=6$... $rg,mm=10$... $100\%=10$
14. *T. keukenschrijveri* Walch
Wild (134/11) ... $Mn=4...$... $md=4$... $rg,mm=7$... $100\%=8$
16. *T. burmensis* Ewing
2 day (2/1) ... both 2 days
Wild (4/3) ... $Mn=2.5$... $md=1$... $rg,mm=3,$... $100\%=3$
17. *T. muridia* Womersley
Wild (15/3) ... $Mn=3.5$... $md=3$... $rg,mm=6$... $100\%=5$
18. *T. consueta* Womersley
Wild (13/3) ... $Mn=11$... $md=8$... $rg,mm=12$... $100\%=15$
22. *T. hastata* Gater
1 and 2 day (4/2) three for 9 days, one 8 days
Wild (7/4) ... $Mn=10$... $md=10$... $rg,mm=12$... $100\%=19$
25. *T. parmisfera* Womersley
Laboratory (13/1) all 2 days
27. *T. rara* Walch (on skinks)
Wild (60/2) ... $Mn=13$... $md=15,$... $rg,mm=40$... $100\%=30$
36. *Blankaartia [Tragardhula] acuscutellaris* (Walch)
Wild (25/2) ... $Mn=5...$... $md=5$... $rg,mm=10$... $100\%=12$
38. *Euschöngastia (Walchiella) oudemansi* (Walch)
1 day (11/2)... ... $Mn=8.4+1.0$... $md=11$... $rg,95\%=11$
Wild (372/12)† ... 18 ... 12 ... $rg,mm=19$... $100\%=32$
50. *Euschöngastia lacunosa* (Gater)
Wild (51/9) ... $Mn=7...$... $md=7$... $rg,mm=13$... $100\%=18$
58. *E. n. sp. nr. raui*
Wild (19/4) ... $Mn=21$... $md=26$... $rg,mm=34$... $100\%=40$
59. *E. n. sp. No. C.O.R.U.-21799*
Wild (7/4) ... $Mn=3...$... $md=4$... $rg,mm=5$... $100\%=6$

* including abnormal extreme value

† but most of these chiggers were on 2 rats

60. *E. (Helenicula) mutabilis* (Gater)
 1 day (7/3) ... $Mn=6.7+1.2$... $md=4$... $rg,95\%=8$
 Wild (4/4) 1 and 2 days
69. *Walchia lewthwaitei* (Gater)
 1 day (82/4)... $Mn=5.7+0.2$... $md=5$... $rg,95\%=9$
 Wild (2/2) 10 and 12 days
73. *W. turmalis* Gater
 Wild (693/12) ... $Mn=5.6$... $md=5$... $rg,mm=10$... $100\%=8$
74. *Schöngastiella* n. sp. nr. *bengalensis*
 1 day (6/2) ... $Mn=13.5+2.9$... $md=15$... $rg,95\%=21$
 Wild (4/2) 1 and 10 days
85. *Gahrlepiea fletcheri* (Gater)
 1 and 2 days (10/2) $Mn=4.6+0.7$... $md=6$... $rg,95\%=6$
 Wild (90/8) ... 5.4 ... 4 ... $rg,mm=8$... $100\%=9$

LIST 2

Chiggers for which only fragmentary information is available.

All from wild-caught rats unless otherwise indicated.

42. *Euschöngastia audyi* (Womersley)
 One for 2 days, three for 8 days when rat died.
43. *E. indica* (Hirst)
 The records for this chigger are very difficult to interpret. Evidently it feeds for a very long time, longer than for any other species recorded, and too long for host rats to be kept in small cages in the present style. Records from wild-caught and 2-day rats indicate a *minimum* feeding time of at least 12 days and a maximum of possibly some months, but of forty-nine chiggers from seven 1-day rats only four fed for more than 15 days, giving a mean time of 9 days. Such an inconsistency may indicate different biological races, or a feeding time which varies with host behaviour, and is being further investigated.
51. *E. nadchatrami* (Womersley), one, for 3 days
55. *E. n. sp. nr. lacunosa*, one for 1 day
62. *Ascoschöngastia malayensis* (Gater)
 Seventeen for 8 days when the rat died
- 64A. *Doloisia* (new subgenus) 'VN' Audy (this *Study*, p. 159).
 (3/2) for 9, 11 and 14 days
65. *Walchia brennani* (Womersley), one, for 2 days.
- 65A. *W. brennani* var *ventralis* (Womersley), one for 9 days
66. *Walchia disparunguis* (Ouds), one for 3 days
68. *W. pingue* Gater (4/3), 1, 2, and 8 days
76. *Schöngastiella arona* Traub and Evans (this *Study*, p. 95) one for 1 day
78. *Gahrlepiea cetrata* Gater, one for 1 day
- 79A. *G. sp. nr. decora* (perhaps two spp), 2 and 3 days
80. *G. insigne* Womersley (3/1) 1, 2 and 6 days
- 85A. *G. sp. nr. fletcheri* (4/2) 3, 4, 6 and 10 days.

TABLE 3

A SUMMARY OF ESTIMATED FEEDING TIMES OF THOSE SPECIES FOR WHICH REASONABLY COMPLETE DATA ARE AVAILABLE.

Species					Mean	Maximum
<i>Trombicula wichmanni</i>	...	...	...	...	4	5
<i>T. akamushi</i>	...	...	...	...	2.8	6
<i>T. deliensis</i>	...	...	...	...	3.0	8
<i>T. sp. nr. bodensis</i>	...	...	...	...	7	10
<i>T. keukenschrijveri</i>	...	...	...	...	4	8
<i>Euschöngasta oudemansi</i>	...	...	...	...	10	19
<i>Euschöngastia lacunosa</i>	...	...	...	...	7	18
<i>E. sp. nr. raii</i>	...	...	...	...	21	40
<i>E. mutabilis</i>	...	...	...	...	6	8
<i>Walchia lewthwaitei</i>	...	...	...	...	6	10
<i>W. turmalis</i>	...	...	...	...	6	10
<i>Schöngastiella sp. nr. bengalensis</i>	...	...	...	...	14	21
<i>Gahrlepieia fletcheri</i>	...	...	...	...	5	9

Discussion

Results such as those presented here are necessarily incomplete, since as long as work continues information is being added, giving more accurate estimations and increasing the list of species. If the results are ever to be used they must be summarised. They could be summarised for each species as they reach a predetermined level of accuracy, or they could be summarised for all species from time to time. The latter method is being followed here, so that this is likely to be the first of a series of such summaries.

The results for *Trombicula akamushi* and *T. deliensis* suggest that the different methods of estimation used are reasonably in agreement, but indicates equally that too close an agreement is not to be expected. The method of estimating from wild-caught specimens by converting proportions to angles is found to give reasonable results when the records are evenly distributed from a number of rats, but when an unduly large proportion of the chiggers are recorded from only a few of the rats the estimates are liable to serious errors.

These figures may be compared with the first approximations offered for certain species in India by Audy (1947) who however did not give detailed information in his unpublished report. Most of the observations were made in the cool dry season of Imphal (after November, 1945). *T. deliensis* and *T. longiseta* ('species L') appeared to complete their feeding in 2-5 days. The "winter" species of *Euschöngastia* (subgen. *Helenicula*, Audy, this Study p. 152) *E. lanius* (reported as *E. mutabilis*) and *E. kohlsi*, appeared to feed frequently for 5-10 days, and two gahrlepieiines (*Walchia enode* and *Schöngastiella ligula*) for 4 or more weeks, after capture of their hosts. Michener (1946) observed in America that larvae of *T. (Eutrombicula) batatas* (very close to the *T. wichmanni* of Malaysia) fed for 2-10 days on chickens, the great majority detaching after 3-4 days. Wharton (1946) reported feeding-times of 10-32 days of *Euschöngastia indica* in Guam, while Wharton and Fuller (1952) quote various similar accounts; several workers have observed that the feeding times of American scrub-itch chiggers vary according to the season and the host (warm or cold blooded).

Summary

1. In order to estimate actual populations of trombiculid mites, or to compare populations of different species on the basis of infestation data, we must have estimates of the mean feeding times of the larvae (chiggers).
2. Feeding times were estimated by keeping infested rats and mice in small cages over trays of water and counting the chiggers which had detached daily.
3. Chiggers from three sources were timed: laboratory bred chiggers fed on white mice; those found on marked rats which had been trapped within two days of release: and those on trapped wild rats of unknown origin.
4. The interpretation of results from chiggers of the first two groups is straightforward. Chiggers of the third group, however, have been on the rat for an unknown period before trapping. Two methods of estimation from the observed data are tried and give reasonably consistent results.
5. Estimates of the mean, modal, and maximum feeding times are given for 21 species, and casual records for 15 more.

References

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SIGMACTENUS ALTICOLA AND *NEOPSYLLA LUMA*, NEW SPECIES OF FLEAS
FROM NORTH BORNEO

By

ROBERT TRAUB

During investigations on arthropod vectors and rodent reservoirs of disease, a joint U.S. Army and British Colonial Office Unit research team operated in North Borneo in July and August, 1951. A second such unit continued the studies in May and June of 1952. In connection with these studies, many valuable fleas, mites and ectoparasites were collected from small mammals, particularly on Mt. Kinabalu. Among the fleas taken were a new species of *Sigmactenus* Traub, 1950 (Ceratophyllidae, Leptopsyllinae) and an undescribed species of *Neopsylla* Wagner, 1903 (Hystriophyllidae, Neopsyllinae), described and illustrated below.

***Sigmactenus alticola* n. sp.** (figs. 1-12).

Diagnosis.—Near the genotype, *S. wernerii* Traub, 1950, which has been described and illustrated in detail, but separable as follows: Male eighth sternum (fig. 10) much more narrowed subapically and bearing two long subapical bristles instead of being of approximately uniform width to near apex and bearing a distal marginal group of four bristles scarcely longer than adjacent lateral bristles. Distal arm of male ninth sternum (fig. 12) lacking a distinct median lobe bearing a prominent tuft of dark bristles; with fewer lateral and ventromarginal bristles, i.e., the marginal bristles only about four in number and these near middle of arm, whereas in *S. wernerii* about 20 bristles extend along or near the entire ventral margin. Aedeagal crochet (fig. 4, CR) narrower, dorsally more arcuate, apex subrounded; not angulate dorsally and subacuminate apically. Female seventh sternum (fig. 9, 7S) with upper lobe typically shorter than ventral one, instead of vice versa. Anal stylet of female (fig. 7) three times as long as broad, instead of merely twice as long as broad.

Description.—*Head* (fig. 1, Male). Pre-antennal region with three long bristles, the uppermost inserted next to base of first (topmost) genal spine at level of minute frontal tubercle; remaining two bristles in a vertical row; of these the uppermost usually at level of fifth or sixth genal spine, near midpoint of comb; third bristle median, at level of third or fourth spine. With a marginal clypeal row of five to seven small thin bristles, interspersed among submarginal sclerotized lattice-work or incrassation characteristic of genus; with a row of about six small bristles on the frons ranging from level of uppermost spine of comb to top of head, above and in front of the vestigial eye (*E*) which, as in other species of the genus, has been pushed to near top of head by hyperdevelopment of genal ctenidium. Genal comb with spines varying in number from 9 to 11. Maxillary lobe extending to near apex of third segment of maxillary palpus. Labial palpi five-segmented extending to slightly less than three-fourths length of forecoxae. Male antenna with first segment bearing a small dense tuft of bristles above dorso-apical angle; the tuft lacking in female. Bristles of second antennal segment very short in male, not extending beyond proximal third or fourth of club; in female one bristle of this segment reaches beyond apex of club. Antennal club in male appearing to be secondarily divided so that club seems to have 15 to 17 segments if dorsal (anterior) divisions are counted rather than ventral. Postantennal bristles usually arranged 4-3-3-6 but with one or two additional bristles placed between first two rows.

Thorax. Pronotum with two rows of bristles and a comb of about 11 or 12 long thin spines per side. Portion of pronotum bearing longest and lowest bristle of second row overlapping prosternosome Mesonotum (Fig. 8, MSN) with three rows of bristles and three pseudosetae (*PS.S*) per side; two pseudosetae subdorsal and one ventral. Mesepisternum (*MPS*) with about three to five bristles. Mesepimere (*MPM*) usually with six bristles, arranged 3-3. Metanotum (*MTN*) with three rows of bristles; its flange with an apical tooth on each side. Lateral metanotal area (*L.M*) well demarcated; with two bristles. Metepisternum (*MTS*) with a single subdorsal bristle; squamulum well developed. Pleural arch (*PL.A*) strongly convex well developed. Metepimere (*MTM*) usually with about eight or nine bristles, arranged 4 (5)-3-1; spiracles subglobose.

Legs. Essentially as in *S. wernerii*.

Abdomen. Small subdorsal teeth on posterior margins of first few segments usually arranged as follows: Male, 2-2-2-1-1 (per side); female, 2-2-1-1. Male with middle antesensillary bristle almost thrice the

length of the others (fig. 5, *A.B*) Female typically with four antesensillary bristles (fig. 9, *A.B*), the second the longest, more than twice length of first and third; the fourth almost twice the length of first and third.

Modified Abdominal Segments, Male (fig. 5). Eighth tergum (8*T*. and fig. 3) with about five long caudomarginal bristles; with about six median bristles between this row and spiracle; with a row of small bristles anterior to the above spiracle. Eighth sternum (8*S* and fig. 10) about two and one-half times as long as broad at base, somewhat sinuate; apically slightly upturned, narrowing at distal third but apex ovate; proximal half of segment nude; ventral margin with a subapical long stout bristle; proximad to this another equally long bristle; with about 8 or 10 smaller lateral, submedian bristles scattered on remainder of distal half. Immovable process of clasper (*P*. and fig. 11) about two and one-half times as long as broad at level immediately below acetabulum; apically subrounded, its anterior margin bearing five bristles, this row extended proximad by three or four additional smaller mesal bristles; posterior margin with one fairly long thin apical bristle and a smaller subapical one. Movable finger or digitoid (*F*) long and narrow, about six times as long as broad, sides subparallel but slightly curving cephalad; caudal margin with four fairly stout bristles; of these one is subapical, the second, somewhat stouter, is at proximal fifth, the third slightly distad of midpoint and the fourth at proximal third; with two rather approximated long thin bristles both above and below the ventralmost of the four large ones. Manubrium (*MB*) and proximal arm of ninth sternum (*P.A.* 9) much as in *S. werner*i. Distal arm of ninth sternum (*D.A.* 9 and fig. 12) long and narrow, more than ten times as long as broad at midpoint; undifferentiated into proximal and ventral lobes or halves; with an apical stout bristle or subspiniform; with two long thin subapical bristles; immediately proximad one to three thin bristles; caudal (ventral) margin with three or four bristles at apical fourth, at shallow sinus; opposite these, with three or four anteromarginal bristles.

Aedeagal apodeme (*AE.A*) somewhat longer than portion of aedeagus caudad of well-developed proximal spur (*P.S* and fig. 4); with a conspicuous pair of movable subdorsal lobes homologous to the distolateral lobes of *Peromyscopsylla* (Johnson and Traub) and herein also designated *DL.L*. Lateral lobes (*L.L*) prominent; with a deep apical sinus, ventrally fairly straight. Sclerotized inner tube with its apex (*A.S.I*) sharply upturned, talon-shaped. Armature of inner tube (*A.I.T*) represented as a short spur at base of sclerotized inner tube. Band of inner tube (*B.I.T*) sclerotized and extending distad of lateral lobes. Median dorsal lobe (*M.D.L*) weakly sclerotized. Crochet very long, much longer than aedeagal endchamber; more than about three and one-half times as long as broad at maximum. The lightly sclerotized dorsal wing convex; apex of crochet ovate; ventral margin straight below insertion of barrel-shaped or peg-like sclerite characteristic of Ceratophylline crochets.

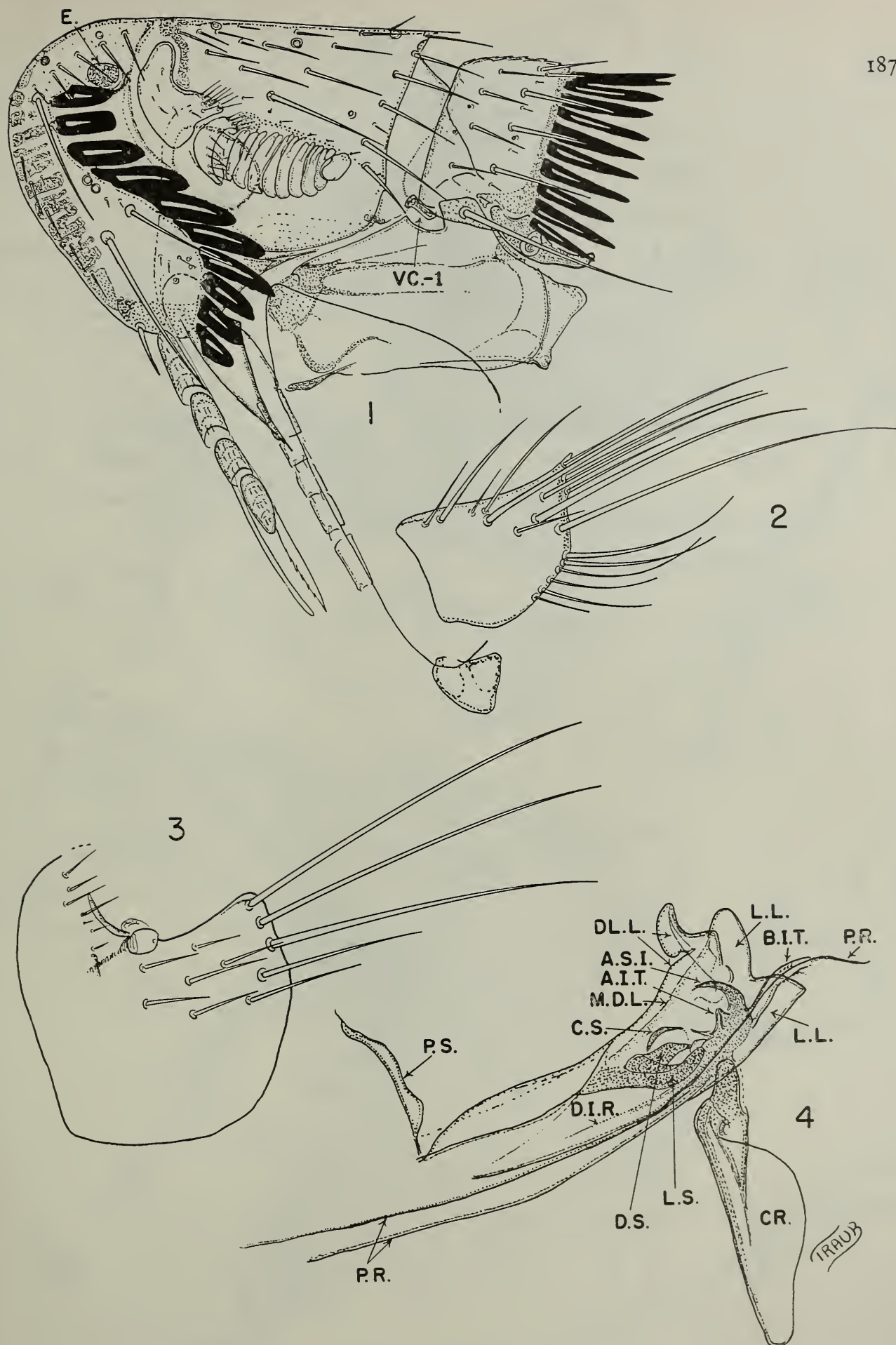
Modified Abdominal Segments, Female (fig. 9). Seventh sternum (7*S*) with caudal margin bearing a deep, fairly broad sinus, the resulting upper lobe irregularly but broadly rounded; ventral lobe slightly longer and broader, less rounded. Ventral portion of seventh sternum with a horseshoe-shaped row of about five or six stout bristles; three or four of these are caudomarginal and two or three ventromarginal. Anterior to this row a group of about five to seven smaller irregularly spaced bristles curving along ventral margin. Eighth tergum (8*T*.) essentially as in *S. werner*i. Eighth sternum (8*S*) weakly sclerotized but large, extending caudad to level of mesal group of three bristles near caudal margin of eighth tergum; devoid of bristles. Anal stylet (*A.S* and fig. 7) about three times as long as broad; with two long stout apical bristles; a ventral bristle about one-third to one-half length of apical bristles; at times with a second ventral bristle subapical in position. Ventral anal lobe (fig. 2) more than two-thirds as broad as long; dorsal margin sinuate; ventral margin essentially convex, not angled, evenly merging with caudal margin; with a group of five or six bristles at height of convexity, i.e., where ventral and caudal angles merge; above this three or four long marginal bristles and two long submarginal bristles; with a long submedian bristle, one or two short ones and three or four dorsomarginal bristles. Spermatheca (*SP* and fig. 6) with head longer than broad, dorsally convex; ventral margin concave; tail narrow, longer than head; tail slightly recurved apically but not extending over head. Bursa copulatrix (*B.C*) ovate or pyriform, its ductus (*D.B*) well sclerotized, slightly curved.

Types.—Holotype male and allotype female ex *Rattus alticola*, North Borneo, Mt. Kinabalu, Tenompok, elevation 4,500 feet; collected by Robert Traub, 2nd July, 1951. Paratypes as follows (all from Mt. Kinabalu, collected by R. Traub or with David H. Johnson in July, 1951): five males and 26 females with same data as holotype; three males, six females ex *Rattus rajah* group, *ibid.*; one male, one female ex *Rattus whiteheadi*, *ibid.*; one female each ex *Rattus cremoriventer* and *R. infraluteus*, *ibid.*; one female ex *R. alticola*, Lumu Lumu, elevation 6,300 feet, in the cloud forest; one male ex *Tupaia montana bahuensis* and one female ex *Rattus rattus bahuensis*, at Kamborangah, elevation 7,800 feet. Additional paratypes collected by J. R. Audy in June, 1952, *loc. cit.*: three males, three females ex *Rattus alticola*, Tenompok; two males and one female ex *Rattus cremoriventer*, *ibid.*; one male ex *Rattus infraluteus*, *ibid.* Holotype, allotype and four paratypes deposited in the U.S. National Museum (Holotype, U.S.N.M. No. 61806). Paratypes deposited in the British Museum, the U.S. National Museum, the Canadian National Collection, the Chicago Natural History Museum, the Rocky Mountain Laboratory of the U.S. Public Health Service, the Plague Investigation Section of the U.S. Public Health Service, San Francisco, the author's collection, and various other institutions.

Comment.—*Rattus alticola*, a denizen of the mountain forest, is apparently the preferred host of *Sigmactenus alticola*. The known range of this flea is between 4,000 and 7,800 feet on

LIST OF ABBREVIATIONS

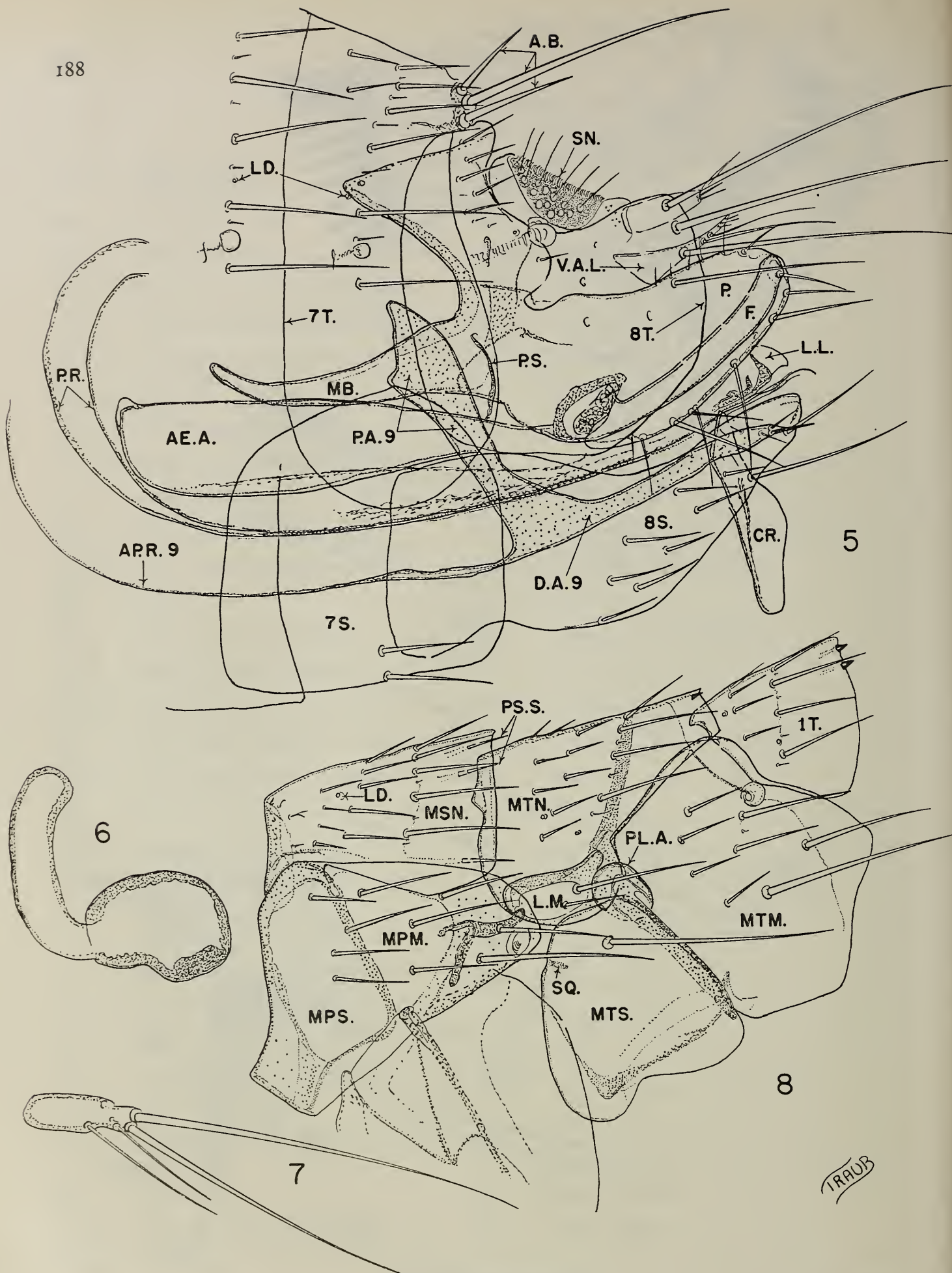
A.A.R.	Third aedeagal rod (accessory apodemal rod).	MPS.	Mesepisternum.
A.B.	Antesensiliary bristle.	M.S.	Median sclerite of apodemal strut of aedeagus.
AE.A.	Aedeagal apodeme.	MSN.	Mesonotum.
A.I.T.	Armature of sclerotized inner tube.	MTM.	Metepimere.
AP.A.	Apical appendage of aedeagal apodeme.	MTN.	Metanotum.
AP.R.9	Apodemal rod of ninth sternum.	MTS.	Metepisternum.
A.S.	Anal stylet.	N.	Neck or constriction of aedeagus.
A.S.I.	Apex of sclerotized inner tube.	P.	Immovable process of clasper.
A.S.T.	Apical sclerites of inner tube.	P1	Anterior process of immovable clasper.
B.C.	Bursa copulatrix.	P2	Posterior process of immovable clasper.
B.I.T.	Band of sclerotized inner tube.	P.A.9	Proximal arm of male ninth sternum.
B.P.W.	Base of wall of aedeagal pouch.	PL.A.	Pleural arch of metathorax.
CR.	Crochet.	P.R.	Penis rod.
C.S.	Crescent sclerite of aedeagus.	P.S.	Proximal spur of aedeagus.
D.A.L.	Dorsal anal lobe of proctiger.	PS.S.	Pseudosetae.
D.A.9	Distal arm of male ninth sternum.	P.W.	Wall of aedeagal pouch.
D.B.	Ductus bursae copulatrix.	S.I.T.	Sclerotized inner tube of aedeagus.
D.I.R.	Dorsal intramural rod of aedeagus.	SN.	Sensillum.
D.L.	Distodorsal lobe of aedeagus.	SP.	Spermatheca.
DL.L.	Distolateral lobe of aedeagus.	SQ.	Squamulum.
D.S.	Dorsal lobe of apodemal strut of aedeagus.	V.	Vesicle of aedeagus.
E.	Eye.	V.A.L.	Ventral anal lobe of proctiger.
F.	Movable finger or digitoid of clasper.	VC.1	First vinculum.
I.R.	Intramural rod of aedeagus.	V.P.	Subanal sclerite.
LD.	Lucodisc.	7S.	Seventh sternum.
L.L.	Lateral lobe of aedeagus.	8S.	Eighth sternum.
L.M.	Lateral metanotal area.	7SPC.	Seventh spiracle.
L.S.	Lateral sclerite of apodemal strut of aedeagus.	8SPC.	Eighth spiracle.
MB.	Manubrium.	1T.	First tergum.
M.D.L.	Median dorsal lobe of aedeagus.	7T.	Seventh tergum.
MPM.	Mesepimere.	8T.	Eighth tergum.



Sigmactenus alticola n. sp.

Head and prothorax, Male	1	Eighth tergum, Male	3
Ventral anal lobe, Female	2	Endchamber of aedeagus	4

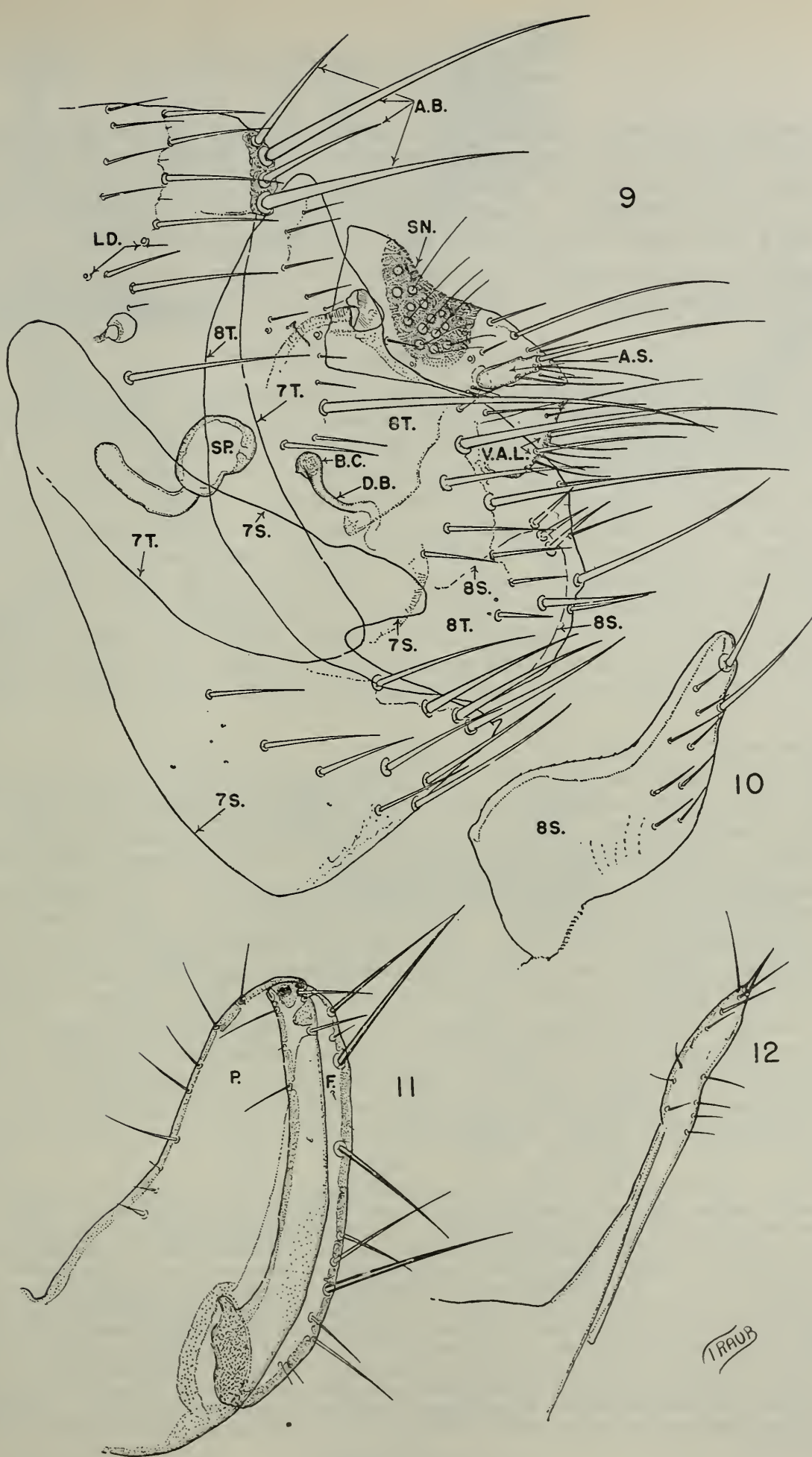
(See p. 186 for list of abbreviations)



Sigmactenus alticola n. sp.

Modified abdominal segments, Male	5	Anal stylet	7
Spermatheca	6	Meso- and metathorax, Male	8

(See p. 186 for list of abbreviations)



Sigmactenus alticola n. sp.

Modified abdominal segments, Female	9	Immovable process and digitoid of clasper	11
Eighth sternum, Male	10	Distal arm of ninth sternum	12

(See p. 186 for list of abbreviations)

Mt. Kinabalu, North Borneo. *Rattus alticola* was also found only between these points. It should be pointed out that collections were somewhat limited immediately above and below those points. This flea was never taken in the lowlands, and of course *Rattus alticola* is not known in such an environment. *Rattus sabanus*, *R. cremoriventer*, *R. whiteheadi*, *R. rattus*, *R. rajah*, and *R. rapit* which were taken below 4,000 feet invariably lacked this flea.

It may be of interest to note that 12 *Rattus alticola*, collected by the author in the Cameron Highlands in Malaya at 5,000 feet (Harrison and Traub, 1950) did not carry any species of *Sigmactenus*.

Notes on the Genus *Sigmactenus*

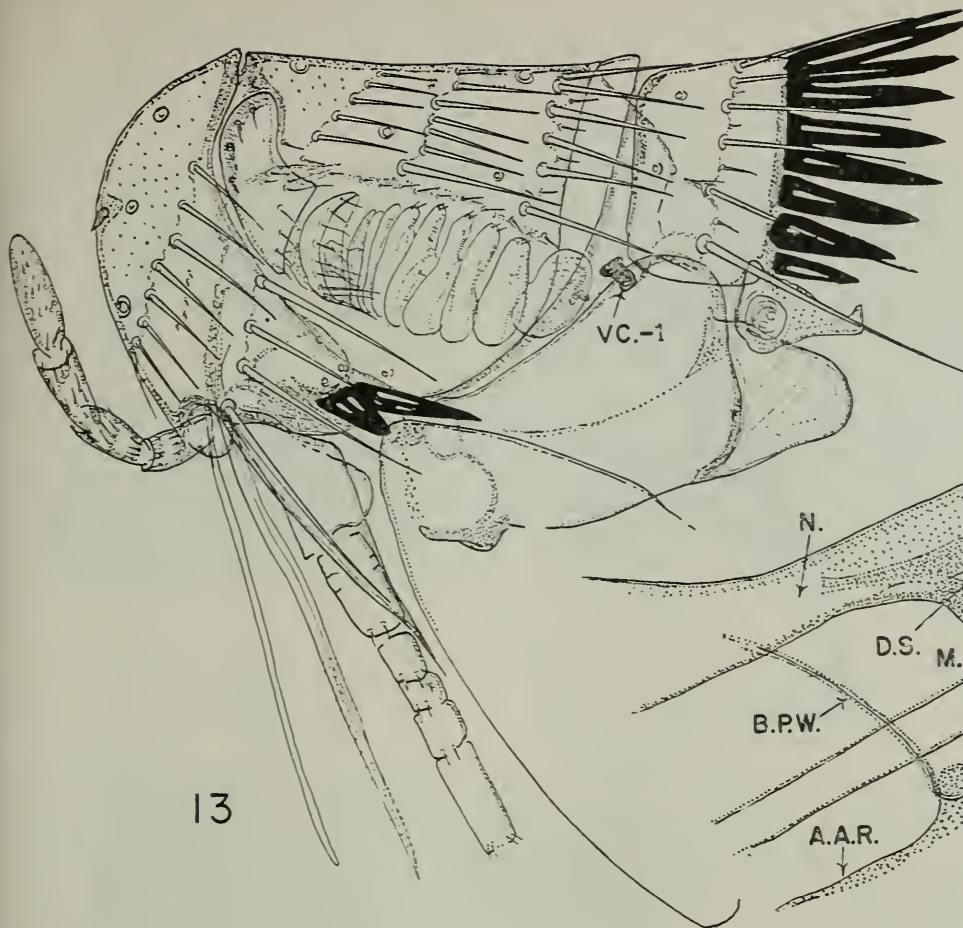
It can now be established that certain features can be added to the generic characterization of *Sigmactenus*. Among these are: the short antennal bristles in the male and the fact that, while most of these are short in the female, at least one bristle invariably seems to be as long as the club; the downward extension of the pronotum over the prosternosome; the well-developed squamulum; uncoiled penis rods; the short compact endchamber of the aedeagus; and the relatively large, although weakly sclerotized, eighth sternum of the female. The dense tuft of bristles on the apex of the first antennal segment of the male in the two described species is an interesting secondary sexual characteristic. This, however, may not be of generic value. The same is probably true of the secondary divisions of the antennal club. The aedeagus of *Sigmactenus* is typical for the subfamily Leptopsyllinae. Particularly characteristic are the compact endchamber and the relatively greatly enlarged crochet. The movable dorsolateral lobes (fig. 4, *DL.L.*) also occur in *Peromyscopsylla* and in *Paractenopsyllus* Wagner, 1938.

Neopsylla luma n. sp. (figs. 13-21).

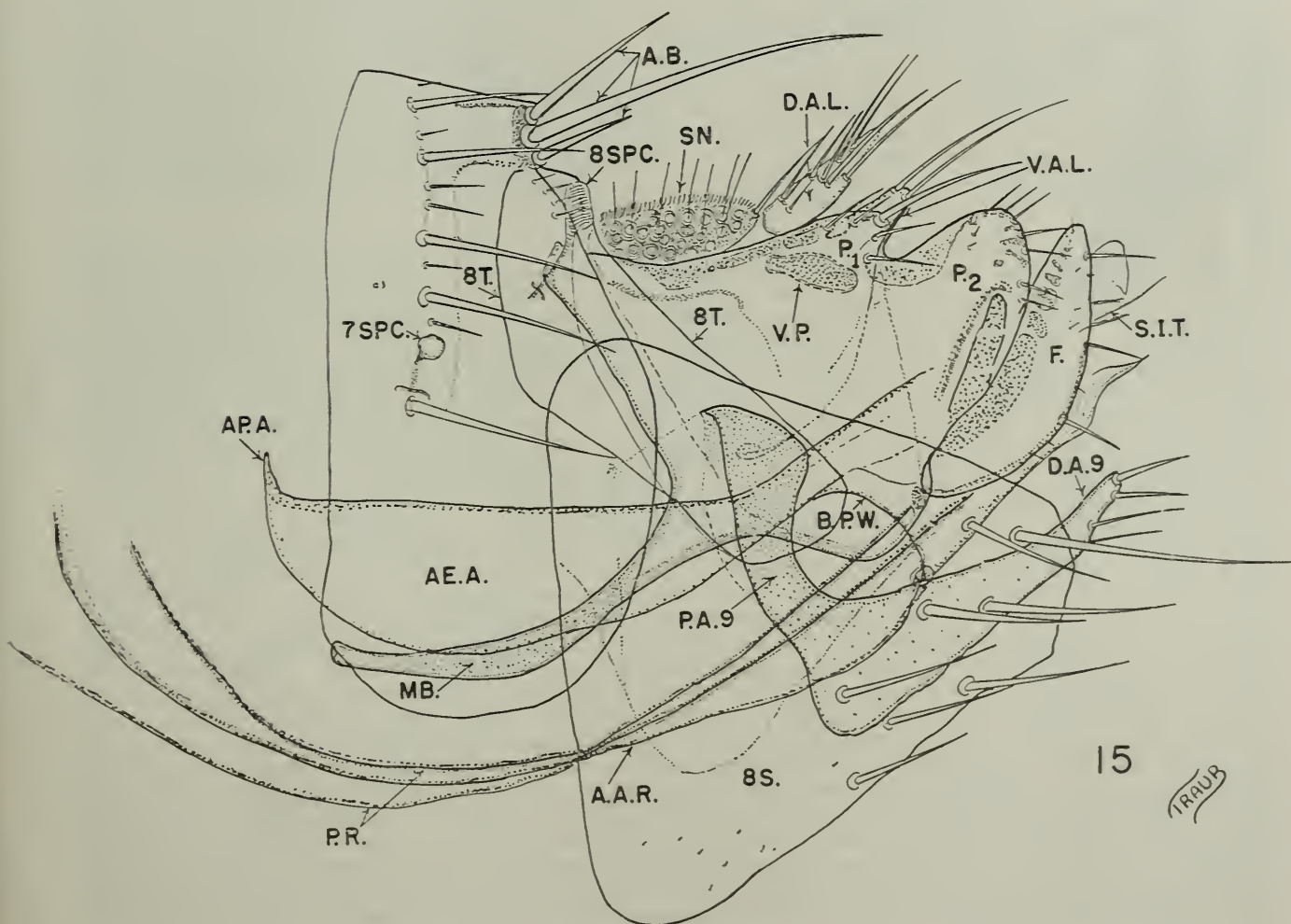
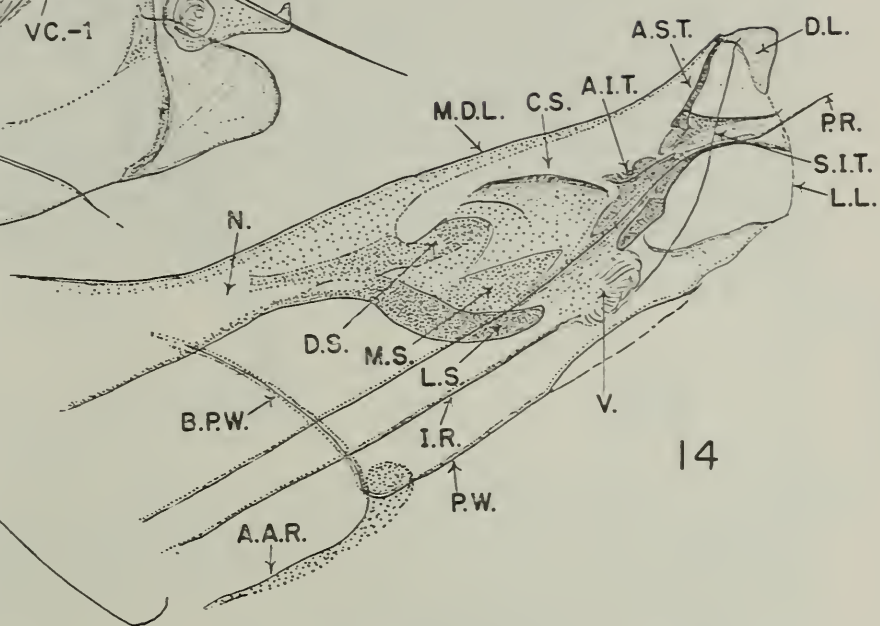
Diagnosis.—Related to *Neopsylla dispar* Jordan, 1932, as evidenced by the following characters: some of the dorsolateral bristles on the hind tibiae forming a false comb; mesal spiniforms on metacoxae; three rows of occipital bristles; the sinus separating P1 and P2 of male clasper broad, somewhat broader than deep; the absence of true spiniforms on the distal arm of the male ninth sternum. Readily separable from *N. dispar* in that: (1) the distal arm of the ninth sternum (D.A. 9. fig. 20) apically narrowed, about six times as long as broad at distal fifth or sixth instead of merely thrice as long; (2) digitoid, or movable finger (fig. 18, *F*) shorter, broader and more rounded, about three and one-half times as long as broad, scarcely extending beyond the apex of P2, its caudal margin evenly and deeply convex, lacking a subtruncate ventral margin; in *N. dispar* the digitoid is $4\frac{1}{2}$ times longer than broad and its apex clearly extends beyond that of P2; there is a subtruncate ventral margin and the posterior margin proximally is only slightly curved; (3) the seventh sternum of the female caudally possessing a dorsal lobe which is broad, the sinus separating the dorsal from the ventral lobe being very broad, subrounded; in *N. dispar*, the upper lobe is long and narrow, acute, while the sinus is also acute.

Description.—*Head* (fig. 13, *Male*.) Frontoclypeal margin evenly rounded but with small but distinct acute median tubercle. First pre-antennal row consisting of 8-9 fairly long thin bristles, in addition at times with one or two smaller ones bordering antennal groove. Second pre-antennal row of four larger bristles, the lowest ventromarginal and the uppermost contiguous with antennal groove. Eye virtually completely vestigial. Mesal spine of genal ctenidium acuminate, longer than broader lateral spine, in ratio of 7-8 to 5. Genal process masked by ctenidium. Maxillary lobe extending to near apex of maxillary palpi. Labial palpi five-segmented but first segment at times appearing secondarily divided. True segments two to four together only slightly longer than first and fifth; the palpi extending slightly less than three-fourths length of first coxa. First antennal segment with a proximal row of anteromarginal bristles; with a subapical row of small thin bristles; proximad to these one or two similar ones. Second antennal segment with an apical fringe of short bristles in male, not extending beyond third segment of club; in female, the subdorsal bristles slightly longer, reaching to near midpoint of club. Postantennal region with three full rows of bristles, usually arranged 7-7(6)-6(7);* with a row of small bristles delimiting antennal groove.

13



14



15

TRAUB

Neopsylla luma n. sp.

Head and prothorax, Male	13
Endchamber of aedeagus	14
Modified abdominal segments, Male	15

(See p. 186 for list of abbreviations)

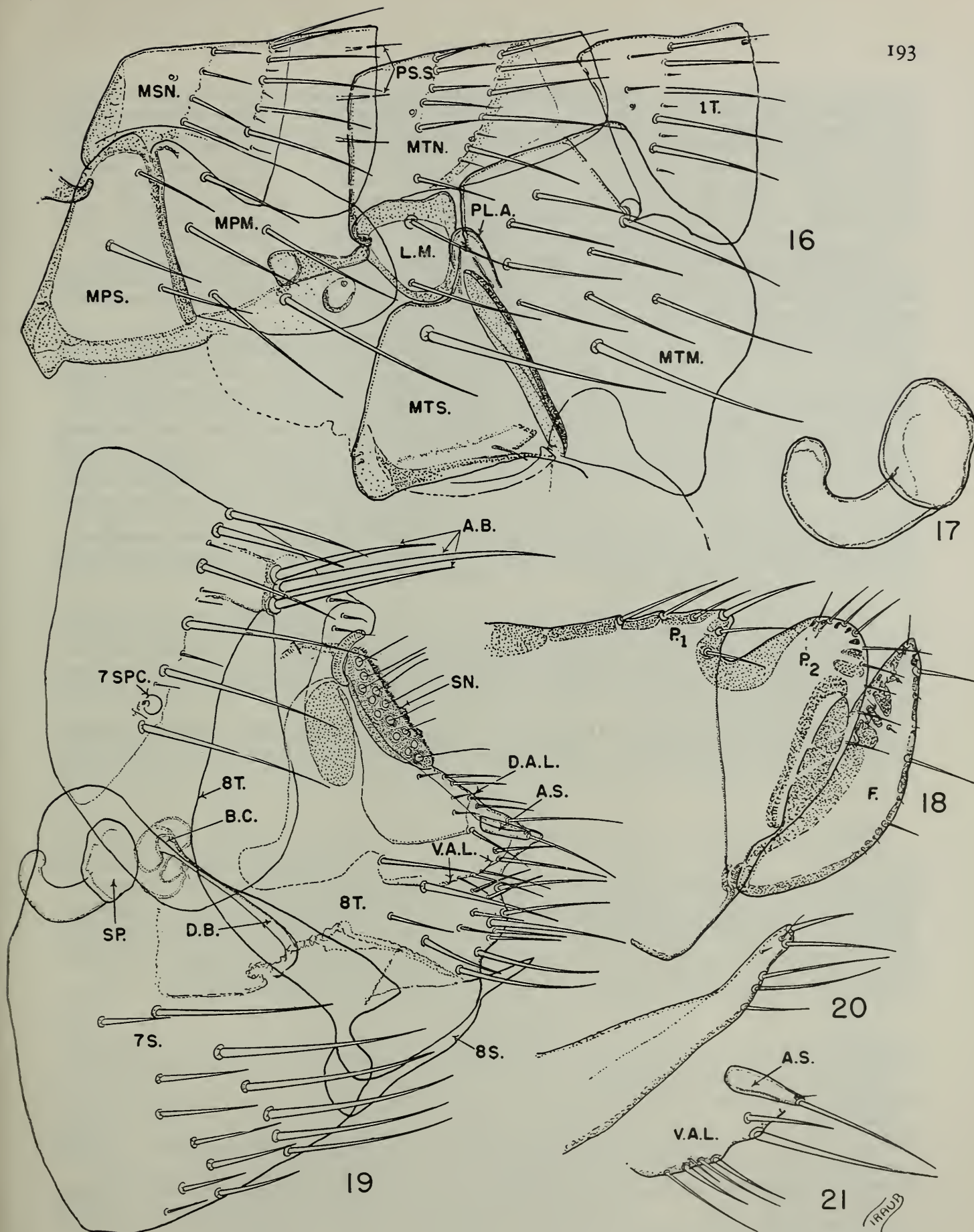
Thorax. Pronotum with one row of about six large bristles; pronotal comb with a total of about 18 spines. Mesonotum (fig. 16, *MSN*) with two rows of bristles; its flange with three pseudosetae (*PS.S*) per side. Mesepisternum (*MPS*) with about two or three bristles, of which one is usually at dorsocaudal angle and another in ventrocaudal region. Mesepimere (*MPM*) with about five bristles, arranged 3-2. Metanotum (*MTN*) with two rows of bristles. Lateral metanotal area (*LM*) broader than long, with two bristles; of these, one subdorsal and one subventral. Metepisternum (*MTS*) with a long subdorsal bristle. Squamulum undeveloped. Pleural arch (*PL.A*) narrow but distinct. Metepimere (*MTM*) with about 9 to 11 bristles, typically arranged 4-4-1 or 5-4-1.

Legs. Metacoxa with a short patch of about eight to 10 mesal spiniforms at anterior margin below midpoint. Profemur usually with one nonmarginal lateral bristle. Relatively longest bristle of tarsus is on first segment of protarsus; this reaches slightly beyond apex of second tarsal segment. No other bristles of any tarsal segment reach beyond apex of following segment. Posteromarginal bristles of mesotarsus I and II particularly enlarged, much longer and stouter than anteromarginals. The same is true for protarsus I. Fifth segment of fore and mid tarsi with four pairs of lateral plantar bristles; in hind tarsus usually with three, at times with four pairs of lateral plantar bristles. Measurements (in microns) of tibiae and segments of tarsi (petiolate base deleted) as follows:

Leg			Tibia		Tarsal Segments									
					I.		II.		III.		IV.		V.	
Pro-	...	...	63	...	33	...	33	...	24	...	21	...	45	
Meso-	...	...	106	...	71	...	49	...	33	...	24	...	47	
Meta-	...	...	120	...	114	...	75	...	47	...	28	...	54	

Abdomen. Terga with apical spinelets arranged as follows (total number): 2-2-2-2-2. On terga three to five the teeth are virtually dorsomarginal, but usually subdorsal in terga one and two. Terga one and two in male usually with the first row of bristles fairly well developed, consisting of two or three bristles; this row much reduced in remaining unmodified terga, usually represented by one or no bristle, that dorsal. Morphological second row of bristles (the only one extant on most terga) extending slightly ventrad of subglobose spiracle. In female anterior row usually consisting of three or four bristles per side on terga one to four; on remainder, of two or three bristles. Second abdominal sterna in each sex with a ventromarginal bristle per side. Typical sterna in male with about two fairly large subventral bristles per side, preceded by one to four small ventromarginals; typical sterna in female with three or four bristles per side, preceded by two to five smaller subventrals or ventromarginals; at times an additional small bristle above row of long ones. In male with three antesensillary bristles (fig. 15, *A.B*), of which middle one is by far the longest, about two or two and one-half times length of uppermost and three times length of lowermost; female with three antesensillary bristles (fig. 19, *A.B*), of which ventralmost is about three-fourths length of middle one and slightly longer than uppermost. Base of *A.B* in male dorsomarginal; in female, slightly removed from dorsal margin.

Modified Abdominal Segments, Male. Eighth tergum (fig. 15, *8T*) reduced to a narrow sclerite; its dorsal margin not extending caudad beyond base of sensillum, ventral margin extending to middle of proximal arm of ninth sternum; tergum about three times as broad as long. Eighth sternum (*8S*) very broad, shaped like an equilateral triangle but with corners subrounded; extending dorsad to about level of seventh spiracle (*7SPC*). Eighth sternum with about eight or nine fairly stout bristles on caudal half, that near dorsocaudal angle the longest; most median or subventral. Immobile process of clasper divided into two lobes (*P1*, *P2* and fig. 18). *P1* distally subacute, with a long apical bristle, below this two submarginal bristles bordering the sinus between the two lobes; with two or three dorsomarginal bristles preceding the stout apical one. Dorsal margin fairly well sclerotized, appearing incrassate. *P2* separated from *P1* by a U-shaped sinus that is well dilated apically so that sinus is slightly broader than deep. Dorsal margin of *P2* broadly and evenly rounded; with four thin bristles; caudal margin slightly convex and with five distal bristles, the row imperceptibly merging with the dorsal one. *P2* three-fifths as broad as long, as measured from midpoint of suture serving as caudal margin of *P1*. Digitoid or movable finger (*F*) about three times as long as broad at maximum; anterior margin relatively straight; posterior margin evenly convex; apex subacute, not extending perceptibly above level of *P2*; caudal margin with three smallish bristles on apical two-thirds, the uppermost subapical, the second at apical third and the ventralmost slightly below midpoint; between these are interspersed very small thin marginal bristles; with a small subapical bristle inserted on anterior margin, which is relatively evenly sclerotized. Manubrium (*MB*) long and narrow, somewhat curved, apical portion fairly straight. Ninth sternum with proximal arm (*P.A.9*) fairly weakly sclerotized, apically expanded and subrounded. Distal arm of ninth sternum (*D.A.9* and fig. 20) slightly longer than posterior arm, narrowing at apical fourth; ventral margin above this point with two or three bristles; subovate apex with two bristles, that at vertex slightly smaller and stouter but nevertheless not subspiniform; with one or two very small subapical bristles and an additional one or two such bristles along distal portion of dorsal margin. Aedeagal apodeme (*AE.A*) broad in the main, portion anterior to base of apodemal strut four times as long as broad at maximum; narrowing at level of *P.A.9* to produce a relatively broad neck (fig. 14, *N.*); apodeme acutely produced at anterior end of aedeagus, resulting in a short apical appendage (*AP.A*). Wall of aedeagal pouch relatively well sclerotized, as is characteristic of genus, its base (*B.P.W*) almost straight, its ventral margin (*P.W*) more lightly sclerotized, somewhat sinuate. Median dorsal lobe (*M.D.L*) lightly sclerotized, shallowly concave



Neopsylla luma n. sp.

Meso- and metathorax, Male	16	Modified abdominal segments, Female	19
Spermatheca	17	Distal arm of ninth sternum, Male	20
Immovable process and digitoid of clasper	18	Anal stylet and ventral anal lobe	21

(See p. 186 for list of abbreviations)

subapically, terminating at apex of rod-like apical sclerite of inner tube (*A.S.T*) which in turn arises from dorsal angle of sclerotized inner tube (*S.I.T*). Agrees with *Strepsylla* in possessing a distodorsal lobe (*D.L*) (Traub and Johnson, 1952); this structure well developed, subcordate or subovate, and arising from apex of *A.S.T*, at junction with *M.D.L*. Lateral lobes (*L.L*) weakly sclerotized. Crochets apparently absent. Sclerotized inner tube subhorizontal, slightly angled ventrad at midpoint; with a proximal dorsal knot-like thickening representing the armature of the inner tube (*A.I.T*). Crescent sclerite (*C.S*) well developed. Lobes of apodemal strut differentiated into a conspicuous lateral ventral sclerite (*L.S*), a more lightly sclerotized subacute mesal sclerite (*M.S*) and a broader, somewhat rounded dorsal sclerite (*D.S*). The vesicle (*V*) at end of intramural rod (*I.R*) lightly sclerotized but nevertheless visible.

Tenth abdominal segment with dorsal lobe of proctiger (*D.A.L*, fig. 15) very well developed, subovate, or conical, about three to five times as long as broad at base (depending upon position when mounted); with about eight or nine bristles, some stout. Ventral lobe of proctiger (*V.A.L*) more lightly sclerotized, with two long apical bristles; with a well-developed subanal sclerite (*V.P*).

Modified Abdominal Segments, Female (fig. 19). Caudal margin of seventh sternum (*7S*) with a fairly broad sinus near ventral margin; the upper lobe angulate, but broad; the lower lobe somewhat rounded; with a row of about six or seven long bristles per side, preceded by an irregular row of about six smaller bristles and two or three ventromarginal bristles. Eighth tergum (*8T*) with three or four small bristles above long thin spiracle, and with two long bristles near base of ventral anal lobe (*V.A.L*); in addition with four long caudomarginal bristles, two shorter caudomarginal bristles between the last two long ones, three lateromedian bristles and a group of four mesal submarginal bristles ventrad to *V.A.L*. Eighth sternum (*8S*) long and narrow, subacuminate; lacking a bristle. Dorsal anal lobe of proctiger (*D.A.L*) with a dorsomarginal fringe of bristles and about four smaller scattered bristles; with a bristle at base of anal stylet. Ventral anal lobe (*V.A.L* and fig. 21) not heavily sclerotized nor angulate; with a proximal group of five marginal bristles, one of which is short, and a subapical group of two bristles, of which the marginal one is quite long. Anal stylet (*A.S* and fig. 21) about three times as long as broad at base, with a long apical bristle and a very small contiguous one. Spermatheca (*SP*, and fig. 17) with head subovate, longer than broad, and tail longer than head, rather upturned. Bursa copulatrix (*B.C*) subovate, its duct rather well sclerotized and fairly straight.

Types.—Holotype male and allotype female *ex Rattus infraluteus*, Mt. Kinabalu, North Borneo. Holotype collected at Kamborangah, elevation 7,800 feet, 7 July, 1951; allotype at Tenompok, elevation 4,500 feet, 18 July, 1951; both collected by R. Traub and deposited in the U.S. National Museum (Holotype, U.S.N.M. No. 61807). Paratypes: Two males, one female with same data as holotype; one male and one female with same data as allotype; one male *ex Rattus infraluteus*, collected by J. R. Audy at Tenompok, 30 May, 1952.

Comment.—*Rattus infraluteus* is apparently the true host of this flea. Despite intensive collecting, no other specimens were taken on any other rats or tree shrews in the same locality.

Summary

Sigmactenus alticola n. sp. and *Neopsylla luma* n. sp. from Mt. Kinabalu, North Borneo, are described and figured in detail. *S. alticola* n. sp. is a characteristic parasite of *Rattus alticola* and is readily separated from *S. werneri* Traub 1950 by the modified abdominal segments. The absence of a prominent median tuft of bristles on the male ninth sternum is diagnostic. *N. luma* n. sp. has been collected only on *Rattus infraluteus*. It is near *N. dispar* Jordan 1932 but is immediately separable by the modified abdominal segments, particularly the narrow distal arm of the male ninth sternum and the short, broad, more rounded digitoid.

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CERCARIAL DERMATITIS CAUSED BY A MEMBER OF THE "ELVAE" GROUP

By

A. A. SANDOSHAM

Professor J. J. C. Buckley (1938), showed that the skin infection known as "sawah itch" among the rice cultivators in Malaya could be caused by the cercariae of *Schistosoma spindale* Montgomery, 1906. He collected *Planorbis exustus* and *Limnaea* sp. from the infected area. Cercariae were obtained only from the *Planorbis*, 8 out of 89 passing the typical Schistosome form. Using these cercariae he produced experimental dermatitis on himself and, by experimental infection of mice, established the identity of the cercariae.

In 1948, the writer received a letter from Dr. Suleiman, Health Officer, Tampin, stating that there were complaints of unusually severe "sawah itch" in the Ayer-Luning District, Negri Sembilan. He was referred to Professor Buckley's work and, in order that the experiment could be repeated, was requested to collect and forward snails of all types (especially those resembling *Planorbis*) from that area.

About a hundred snails, later kindly identified by Dr. W. J. Rees of the British Museum as *Lymnaea crosseana* Mabilie, were received. Of these 72 were alive and 19 extruded cercariae, 13 of them extruding only a furcocercous variety.

Description of Experiment

These furcocercous cercariae were placed on the forearm of the writer in some water and a pricking sensation was evident in four minutes, the intensity reaching its maximum in twelve minutes. Half-an-hour after the commencement of the experiment, the water had not completely dried and it was wiped off. There was no obvious change on the skin at first but a mild itching sensation persisted for about four hours. About three hours after the commencement of the experiment, the skin was slightly raised and somewhat inflamed. The following day the inflammation had subsided and in a week's time no difference could be seen from the normal skin.

Description of Cercariae (fig. 1)

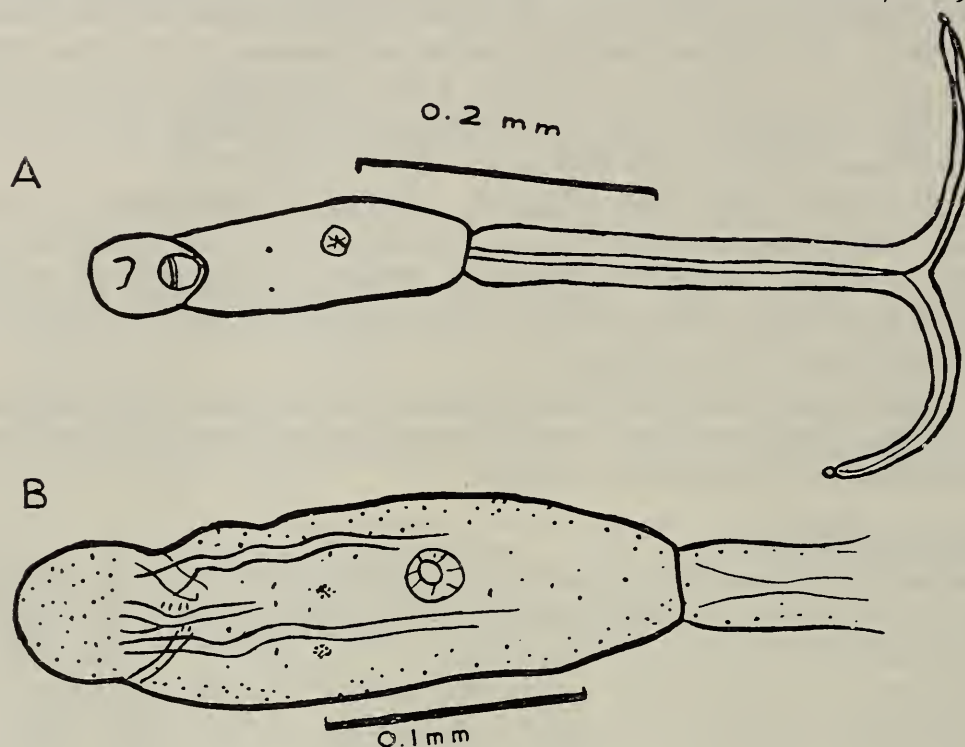
Behaviour.—The furcocercous cercariae are phototactic and negatively geotactic, tending to collect near the surface towards the bright side of the room. They hang head downwards with the tail stem in line with the body but the furcae spread apart. They swim actively for the most part with the tail forwards. On a microscope slide they crawl about with the aid of suckers in a forward direction. The cercariae were dead or moribund in 24 hours.

Morphology.—The body is narrow and elongated being about twice as broad as the tail except when extended. The tail stem is longer than the length of the body. The tips of the tail furcae end in narrow papilla-like projections and the tail furcae are shorter than the tail stem but more than half its length. A pharynx is absent but the posterior portion of the oral organ is muscular. A pair of pigmented "compound" eyespots are present slightly in front of the middle of the body. There are two suckers. The ventral sucker which is muscular and protrusible is situated just in front of the commencement of the posterior third of the body. The surface of the body and tail is studded with numerous minute spines, these being more concentrated at the anterior end. The flame cell pattern could not be definitely established partly from lack of material and partly from the writer's lack of familiarity with this difficult structure. However, a pair of flame cells was definitely made out in the tail stem close to the body. The excretory canal runs down the centre of the tail stem and the furci to the tip.

Vital staining with neutral red showed up a mass of large glands in the posterior part of the body but the outline of the cells was indistinct and it was not definite if there were five or six pairs of glands. Heavy ducts were seen leading from the glandular area towards the anterior end.

The following measurements based on seven specimens were taken from preserved material (measurements in mm.); this material was stained with lithium carmine and brilliant green as recommended by Gordon *et al.* (1934) but no further details could be observed in the penetration glands beyond the fact that the anterior glands took on the stain somewhat differently from the posterior pairs.

Length of body	...	...	...	...	...	...	0.24-0.26
Maximum width of body	...	...	...	...	...	...	0.07-0.08
Length of head organ	...	...	...	...	...	...	0.068-0.069
Maximum width of head organ	...	...	...	...	...	...	0.05-0.053
Diameter of ventral sucker	...	...	...	...	...	...	0.018-0.022
Distance from V.S. to posterior end	...	...	...	...	...	...	0.08-0.09
Length of tail stem	...	...	...	...	...	...	0.28-0.29
Width of tail stem	...	...	...	...	...	...	0.035-0.036
Length of furcus	...	...	...	...	...	...	0.18-0.19
Maximum width of furcus	...	...	...	...	...	...	0.017-0.019



Cercaria malayi I

A, ventral view; B, enlarged ventral view of body.

Experimental Studies

The cercariae were examined carefully to make sure there were no brevifurcous forms of *Schistosoma spindale* variety. Since some of the dermatitis-producing Schistosome cercariae have been shown to be of avian origin in other countries, an attempt was made to infect two chickens by pipetting the cercariae-containing water into their axillary folds. The skin showed numerous red spots in both birds. No eggs were present during the subsequent examination of the stools of these birds. One chicken died three weeks after the exposure to infection and the other was killed one month after the experiment was commenced. Both showed no flukes in their lungs, liver, mesenteric vessels or the venous plexus of the submucosa of the intestines.

Dissection of Snails

A few of the snails that extruded only these furcocercous cercariae were dissected and sporocysts containing these cercariae with pigmented eye spots were obtained in the liver. There were no rediae present in any of the snails. The sporocysts (fig. 8) were elongated bodies about 3 mm long with an irregularly constricted outline.

Discussion

The morphology of the cercariae serves to exclude the human Schistosomes and *S. spindale* from our consideration.

This species falls obviously into the category of non-human furcocercous cercariae generally referred to as the "Elvae" group, several members of which have been shown experimentally

to produce a dermatitis by penetration of the human skin. Cort (1936) lists five such species, namely, *Cercaria ocellata* La Vallete, 1855, *C. douthitti* Cort, 1914, *C. elvae* Miller, 1923, *C. physellae* Talbot, 1936, and *C. stagnicola*, Talbot, 1936. To this list must be added *C. tuckerensis* Miller, 1927, *C. longicauda* Macfarlane, 1944 and *C. oregonensis* Macfarlane and Macy, 1946.

McMullen and Beaver (1945) consider *C. elvae* to be a synonym of *C. ocellata* and Szidat (1942) believes the latter to be more than one species distinguishable only if killed by heat as recommended by Brumpt. Talbot (1936) separated *C. physellae* and *C. stagnicola* from *C. elvae* with which they were previously confused, merely by slight differences in time of emergence, taxes, method of swimming, and attachment. The measurements given for *C. ocellata* by various authors vary quite considerably.

Brumpt (1931) by experimental infection has shown *C. ocellata* to be the larval form of *Trichobilharzia ocellata* (La Valette, 1854). McMullen and Beaver (1945) experimentally obtained the adult forms of *C. physellae* and *C. stagnicola* and found these also to belong to the genus *Trichobilharzia* Skrjabin and Zakharov, 1920. Price (1931) experimentally infected laboratory mice and rats with *C. douthitti* and showed it to belong to the genus *Schistosomatium*.

Thus it would appear that the cercariae belonging to the "Elvae group" do not belong to the same genus and that the classification of these larval forms is somewhat artificial. They also show a considerable degree of variation in their measurements which makes species determination somewhat difficult. Even where the knowledge of the structure of the cercaria and of its parthenita is complete, it is difficult to arrive at a final decision as to specificity except through a series of breeding experiments conducted in order to obtain the final adult stage.

These itch-producing cercariae in Malaya belonging to the "Elvae group" are probably the larval forms of some member of the Bilharziellinae, sub-family of the Schistosomatidae, possibly belonging to the genus *Trichobilharzia*. There is some resemblance to the cercariae of *T. stagnicola* (Talbot, 1936) as well as to *Cercaria oregonensis*. Macfarlane and Macy, 1946. As the post-larval development has not been studied and as the morphological study does not extend to details necessary for species determination the procedure, so widely used, of giving numbers instead of names is adopted and the species is referred to as *Cercaria malayi* I.

It is of interest to record that Macfarlane (1944) in New Zealand noted that the dermatitis following the first exposure to *Cercaria longicauda* was milder than that following re-exposure and suggested that it may be a sensitisation reaction resulting from repeated exposure to the cercariae. To test the validity of this hypothesis, Olivier (1949) carried out a series of human exposures to species of cercariae known to cause dermatitis in the United States. He showed that persons exposed the first time had only mild, innocuous and inconspicuous lesions, like the ones experienced by Professor Buckley and myself. When persons were given additional exposures to relatively small numbers of the same species, the reaction became progressively stronger and the dermatitis more severe. Similarly, Hunter *et al.* (1949) report two cases of what appears to be an allergic response following sensitisation a month previously.

It is probable, therefore, that in Malaya Buckley's sepsis caused by scratching of the lesions only partly explains the ill effects, allergic skin reaction playing a part as well. A careful history taken from the rice-cultivators may help to establish this point. Dr. Suleiman is of the opinion that the complaints of "sawah-itch" are less common from children and young adults working in the rice-fields.

The question has been frequently raised as to whether dermatitis-producing schistosome cercariae could set up a systemic infection in man. Buckley (1938) having described the dermatitis caused by the cercariae of *S. spindale* in Malaya, mentions that there are several records in the literature of cases of human schistosomiasis, which from the characteristic

spindle-shaped eggs found in the faeces or urine, have been diagnosed as being due to *S. spindale* or some very closely related species, and concludes with a warning, "As a potential human parasite, therefore, *S. spindale* must be regarded with suspicion, especially in localities where man, the accidental host, is in close association with normal hosts such as the buffalo and is frequently exposed to infection with this parasite." The writer made a careful examination of the faeces and urine of a number of cases from this district but failed to find any Schistosome eggs.

Penner (1941) who discusses this problem makes the following observation, "Attention should be called to the fact that *Cercaria douthitti*, now shown for the first time to penetrate and migrate through to the lungs, might also go at least this far in man, and particularly in children who swim in infected areas. Whether this worm can go further than the lungs is not known. That the entrance of this species of larval trematode into the lungs might carry infections mechanically from the outside is of potential importance and in the infested areas where wading or swimming is done, may constitute a public health problem not yet realised."

Summary

The existence of cercarial dermatitis among the rice-cultivators of Malaya caused by a member of the "Elvae group" is recorded for the first time.

The snail host is *Lymnaea crosseana* Mabilie.

Unsuccessful attempts to infect two chickens with these cercariae are recorded.

Biological and morphological features of the cercaria and sporocyst are given briefly. The cercaria is provisionally named *Cercaria malayi* I.

The probability of allergy playing a role in the causation of "sawah-itch" in Malaya is discussed.

The negative findings in an examination of a number of paddy cultivators from this district for Schistosome eggs in the faeces and urine is recorded and attention is drawn to the possibility of infections being carried mechanically from the outside.

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STUDIES OF LARVAL TREMATODES FROM SNAILS

By

A. A. SANDOSHAM

FIRST BATCH OF LIVE SNAILS

In order to complete the morphological and life-history studies of the member of the "Elvae" group causing cercarial dermatitis in man in Malaya reported in the preceding paper (Sandosham 1953), a batch of fresh-water snails was flown to London.

About 50 snails, kindly identified by Dr. W. J. Rees of the British Museum as *Lymnaea crosseana* Mabile, had been packed alive in moist charcoal at Singapore and the journey to London had taken five days. All but six were found dead.

The live snails were transferred to some fresh water in separate 3" x 1" tubes and exposed to bright light. Three of the snails discharged cercariae. Snails 1 and 2 discharged two different types of cercariae. One was an echinostome with 37 collar spines and the other a furcocercous variety. Snail 3 discharged two types of echinostome cercariae, one with 37 collar spines and the other, which was slightly smaller, with 43 spines.

Description of Cercariae

Both types of Echinostome cercariae swim powerfully at random by the vigorous movements of the tail, the body being doubled up by bending ventrally while swimming. When not swimming actively, the body straightens out and the cercariae tend to gravitate to the bottom of the container. On a slide and in the bottom of the container, the cercariae creep about fairly rapidly by the alternate use of the two suckers. They remain active for 8 to 10 hours after which they tend to collect at the bottom and finally die at the end of about 24 hours. They exhibit no evidence of phototaxis.

Echinostome Cercaria with 37 Collar Spines (Fig. 1)

The body is elongate, pointed anteriorly and has its greatest width at about the level of the ventral sucker. The body and, to a lesser extent, the tail are capable of a considerable degree of extension and contraction. The measurements given below are of specimens fixed in formalin. The body measures 0.3 to 0.43 mm in length and 0.1 to 0.15 mm in width. The tail is 0.35 to 0.4 mm long and 0.04 mm wide. At the posterior end the tail tapers to a blunt point. In view of the importance attached by Sandground and Bonne (1940) to the presence of fluted fins on the tail in the cercaria of *E. lindoensis* which they described, these were carefully looked for but were found wanting.

The cuticle on both surfaces is covered, more noticeably in the anterior part, with fine spines which can only be seen with difficulty in unstained specimens. They become more evident after staining the cercariae lightly with methylene blue.

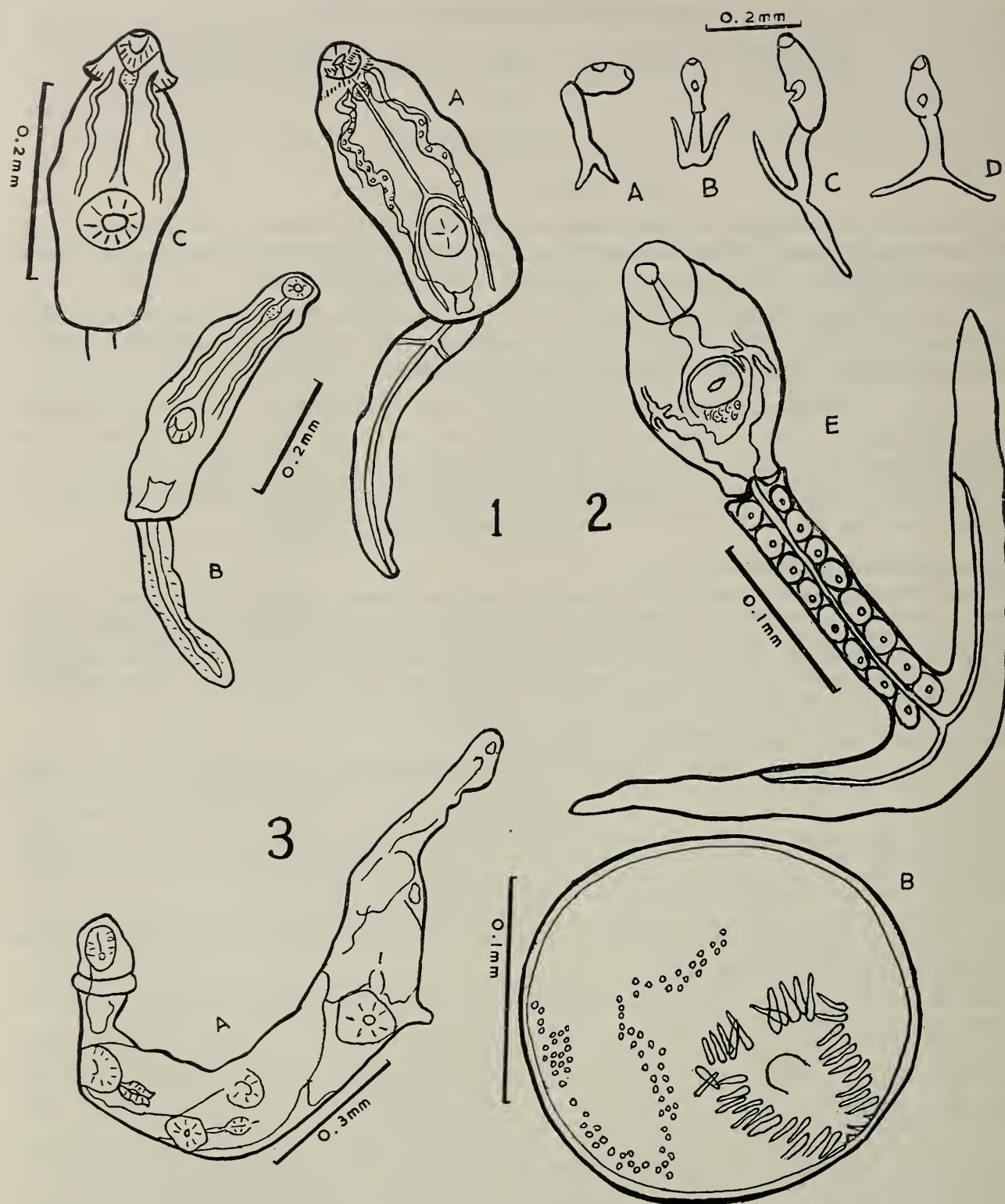
The reniform cephalic collar (which is more prominent in fixed specimens) measures 0.07 to 0.1 mm across and carries 37 spines of approximately the same size arranged in two alternating rows. There is a corner group of 5 spines on each side.

The mouth is subterminal but in preserved material appears terminal in position. The oral sucker measures 0.05 mm in diameter while the ventral sucker, which is behind the middle of the body, measures 0.06 mm. The pharynx measures 0.026 mm long by 0.02 mm broad and is separated from the mouth by a short prepharynx. The oesophagus is 0.09 mm long and bifurcates in front of the ventral sucker into two simple intestinal caeca which extend to near the posterior end of the body.

The excretory vesicle is rectangular with the antero-lateral corners and the centre of the posterior surface drawn out to receive the excretory canals. The main lateral canals are narrow from the bladder to the level of the ventral suckers after which they expand, and become more wavy and filled with numerous dark refractive granules. At the level of the collar they become narrower and free of granules and recurve and continue posteriorly to the end of the body where they again turn forwards. Beyond this level, the fine tubules could not be followed with any degree of certainty. A fine collecting vessel extends from the posterior end of the bladder to the tip of the tail giving off near the proximal part a pair of branches which run outwards to terminate at the sides of the tail. Several flame cells were observed but it was not possible to determine their full number and the pattern and flame cell formulae were not worked out.

Echinostome Cercaria with 43 Collar Spines

This cercaria is very similar to the one described above but can be easily distinguished by the collar spines which number 43 instead of 37 and the corner group is composed of 4 instead of 5 spines. This



1. Cercaria of *Echinostoma revolutum*
A, B, living specimens; C, preserved specimen.

2. *Cercaria malayi IV*
A-D, attitudes assumed under coverglass by living specimens; E, living cercaria under higher magnification (body contracted).

3. Larval stages of *Echinostoma revolutum*
A, mature redia; B, metacercaria.

species is also slightly smaller but the variations in size of these two species allow for overlapping and the difference in size alone cannot be used to sort them out. The cuticular spines are more easily made out in this species. No other difference was noticeable between the two species of cercaria.

Furcocercous Cercariae (Fig. 2)

These are pharyngeal, longifurcate distome cercariae without eye-spots. They are very active and swim almost incessantly tending to collect near the surface towards the darker side of the container. They swim tail foremost with the furcae fully extended and give the impression of a rotating spindle moving upwards. When they come to the surface the swimming ceases, the furcae are spread out and the cercariae tend to sink slowly. The activity of these cercariae slows down in 6 to 7 hours and most of them are dead in 20 hours. When dead, the tail is usually found lying separate from the body and a mass of fine globules collects in the neighbourhood of the oral sucker.

The body, which is somewhat flattened dorso-ventrally, expands and contracts considerably. The tail stem is stout and is of the same thickness as the body when the latter is fully expanded. The furcae are also stout and are as long as the tail stem. The ventral sucker is situated at about the middle of the body or slightly posterior to it. In freshly-dead specimens, the body measures 0.14 to 0.15 mm in length and 0.045 to 0.056 mm in maximum width. The tail stem measures 0.08 to 0.1 mm in length and the furci are 0.1 to 0.12 mm long.

The cuticle in the anterior region is beset with minute spines arranged in transverse rows. Spines are also present over the ventral sucker, being most marked round the margin. The rest of the cuticular surface is smooth.

The anterior organ is globular and is larger than the ventral sucker. There is a short prepharynx followed by the oval or globular pharynx and a short oesophagus which divides in front of the ventral sucker into two long caeca. A mass of granular gland cells are present behind the ventral sucker.

The excretory vesicle is bilobed, the two main collecting canals extending forwards to the front of the ventral sucker. At this level, they meet the lateral ducts and give off on each side a transversely-running duct. The caudal excretory tube sends a branch into each furcal ramus which opens by a pore at about half way down the length of the ramus. The tail stem contains 8 conspicuous pairs of large rounded cells.

Dissection of Snails

Forty dead snails were dissected and eleven had metacercariae and/or rediae in the tissues of the body. Four had tetracotyles.

Description of Rediae

Mature rediae (Fig. 3A) containing about 7 to 10 echinostome cercariae in each were present in large numbers. These rediae are tinged a light orange yellow, possess a collar and locomotory organs. They measure about 1.5 to 2.75 mm long by 0.2 to 0.3 mm broad. The pharynx is about 0.09 mm long by 0.06 mm broad. None of the rediae contained cysts within them.

Description of Metacercariae

In the digestive glands were seen large numbers of free echinostome cercariae some of them without tails probably preparatory to encystment. In the snails with double infection both types of echinostome cercariae were seen lying free in the liver tissues.

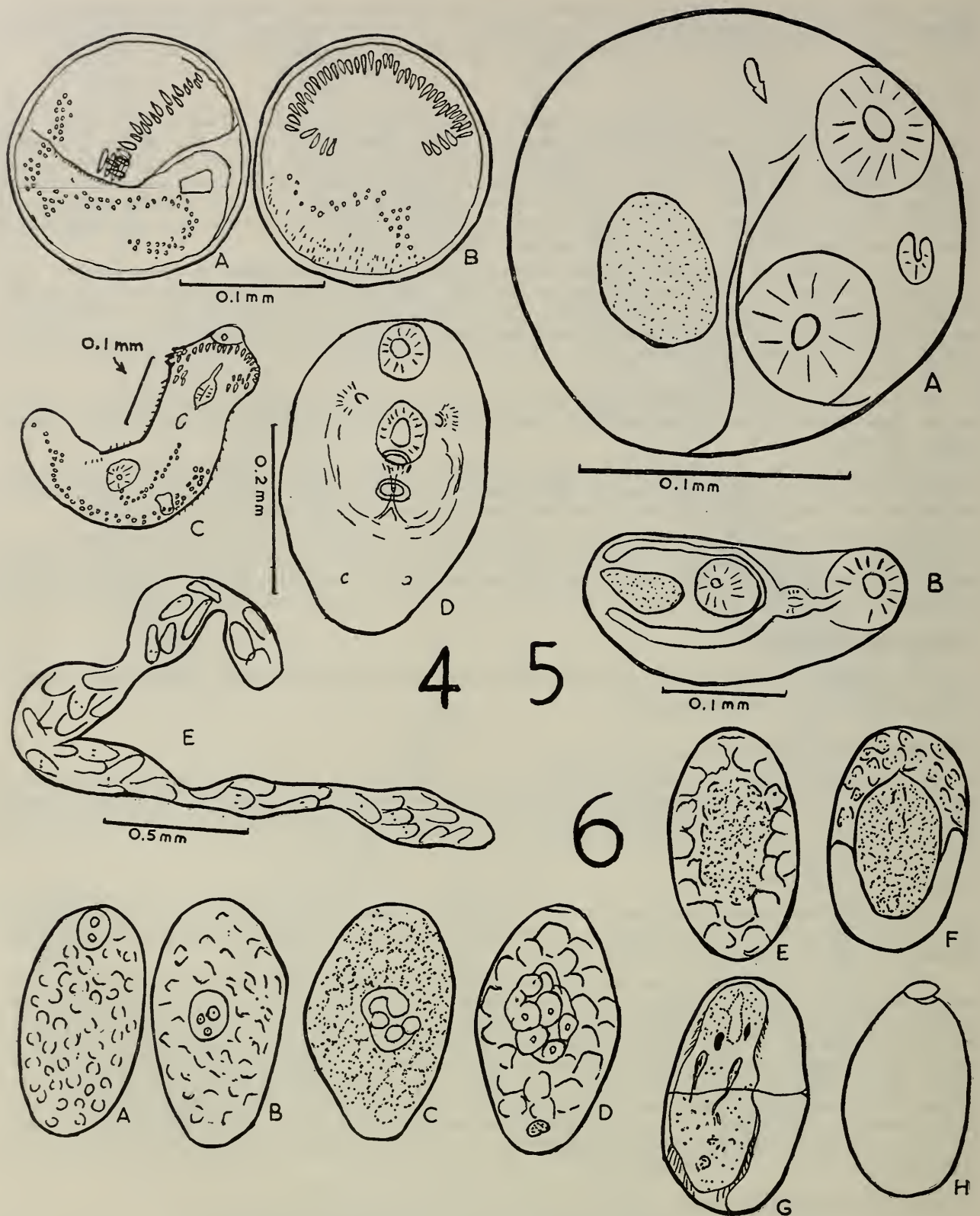
There were also present numerous echinostome metacercariae. These are of two types but both are globular and measure 0.17 to 0.19 mm in diameter. The cyst wall is thick and two-layered. The two types of metacercariae though similar in size and general appearance can be distinguished by the collar and cuticular spines. The one with 37 collar spines (Fig. 3B) shows no evident cuticular spines while in the other with 43 collar spines (Figs. 4A and B), these are prominent. The one with 37 collar spines has five corner spines while the other has only four on each side. Of the eleven snails containing encysted metacercariae, six had both types and five had only one type or the other. The number of metacercariae in the dissected snails varied from about a dozen to a few hundreds in each. A few of the metacercariae were dead, as evidenced by the marked translucency or by their taking on a pinkish stain from the shell of the snail.

Description of Agamodistomes

The agamodistomes (Fig. 4C) released by rupture of the echinostome metacercariae are similar except for the differences in the collar and cuticular spines noted in the encysted forms. The movement is sluggish and consists of expansion and contraction of the body. It measures about 0.5 by 0.1 mm.

Description of Sporocyst

The parthenitae of the furcocercous cercariae are long sporocysts with irregular constriction. These are present in the digestive glands and contain large numbers of cercariae in various stages of development.



4. Larval stages from *Lymnaea crosseana*

A-B, metacercaria of *Cercaria malayi* II; C, agamodistome of *Cercaria malayi* II; D, tetracotyl;
E, sporocyst with *Cercaria malayi* I.

5. *Cercaria malayi* V

A, metacercaria; B, agamodistome.

6. Development of egg of *Echinostoma revolutum*

A, freshly-passed egg; B, one day old egg; C, five days; D, seven days; E, nineteen days; F, twenty days;
G, twenty-one days; H, empty shell with operculum burst open.

Tetracotyles

Four of the dissected snails had a species of tetracotyl, two of these snails having echinostome rediae and metacercariae at the same time. None of the four had sporocysts with bifid-tailed cercariae. The tetracotyles were few in number ranging from two to four in each snail.

These tetracotyles (Fig. 4D) are ovoid bodies measuring about 0.4 by 0.3 mm with the anterior end being more blunt. They appear darker round the periphery. The ventral sucker is situated at varying distances from the anterior sucker up to the middle of the body of the tetracotyle. The auricular depressions which are on either side in front of the ventral sucker, are prominent but incompletely round. The clasping apparatus behind the ventral sucker is prominent with an oval (long axis in the horizontal plane) opening in the centre. The clasping apparatus is most prominent posteriorly in the midventral portion and as its margin encircles forwards and medially it gradually becomes lost. No gelatinous wall is present around the tetracotyl in any of these specimens.

It is possible that these tetracotyles are the later developmental stages of the furcocercous cercariae noted above but none of the *Lymnaea natalensis* exposed to these cercariae had tetracotyles when dissected subsequently (see experiment described below).

The six live snails from Malaya died in the course of two weeks, the two infected ones living longest. Those discharging cercariae died within three days of arrival in spite of their having been transferred immediately to well-aerated water in jars in a room maintained at a constant temperature of 22°C. Dissection showed the presence of the mature rediae and metacercariae of the same two species of echinostomes, mature sporocysts packed with bifid-tailed cercariae and the tetracotyles already described. Only the sporocysts showed some slight evidence of motility.

Metacercaria with Stylet (Fig. 5A)

In addition to the above, one of the snails had a small number of metacercariae with a stylet. These cysts have double cyst walls and the curled up young flukes are very active inside. The stylet was lying free within the cyst and rupturing the cyst wall and freeing the young flukes confirmed that it had been extruded. The cyst is globular and measures 0.15 mm. in diameter. The stylet has a slight thickening behind the tip giving it a spear-head appearance; it was 0.018 to 0.022 mm long. The metacercariae lie doubled up so that the ventral surface of the anterior part of the body is opposed to the ventral surface of the posterior part. There are no eyespots. The two suckers are conspicuous as also is the pharynx, and behind the ventral sucker lies a mass of small spherical concretions filling up an enlarged excretory vesicle.

Description of Agamodistome (Fig. 5B)

The young fluke, freed by the rupture of the cyst wall, contracts and expands actively, is elongate oval in shape and measures 0.22 mm in length by 0.1 mm in maximum width. The ventral sucker is somewhat smaller than the oral sucker and is situated at about the middle of the body. The whole cuticle is spinous but the spines are most prominent in the anterior region. The mouth is subterminal, the prepharynx is long followed by a muscular pharynx. The oesophagus is short and divides in front of the ventral sucker into two long simple caeca which extend to the posterior end. The excretory vesicle filled with fine granules tapers towards the posterior end. The main excretory ducts and the flame cell pattern were not made out. Similarly, it was not possible to delineate the genital rudiment lying behind the dense excretory vesicle. No development of vitellaria was evident.

Experiments with Larval Trematodes

Exposure of Cercariae to Human Skin

About 1 c.c. of water containing furcocercous cercariae was pipetted on to the flexor surface of my forearm and at the end of 15 minutes nothing had happened. Similar experiments with the echinostome cercariae caused no irritation to the skin. It was noted that the cercariae did not encyst on blades of grass, sides of the glass container or on empty snail shells.

Exposure of Cercariae to Snails

In three 3" x 1" tubes, six *Lymnaea natalensis* bred in the laboratory of the London School of Hygiene and Tropical Medicine were placed. To each of these one of the three different types of cercariae liberated by the Malayan *Lymnaea* was added. At the end of two hours it was noted that whereas there had been a considerable diminishing in the numbers of the echinostome cercariae, no noticeable change was seen in the case of the furcocercous cercariae. These snails were transferred to separate jars with well-aerated water in a room maintained at a constant temperature of 22°C.

All these snails died within three weeks while the controls were alive and continued to breed. The snails were dissected as they died and metacercaria of both echinostome species

were present in the tissues of the body but no tetracotyles were seen. It was noticeable that the metacercariae in the snails that died earlier exhibited relatively greater motility within the cyst wall than did those found in the snails that died later.

Feeding Experiments

Six one-week old ducklings were brought from hatcheries and daily examination of faeces over 3 days were negative to eggs of helminthic parasites. Feeding of infective material was carried out as follows :-

Duck A. Given, mixed with food, snail tissues containing approximately 100 metacercariae with 37 collar spines.

Duck B. Similarly fed with snail tissue containing approximately 20 metacercariae with 43 collar spines.

Duck C. Similarly fed with snail tissue containing a mixture of both types of echinostome metacercariae.

Duck D. Similarly fed with snail tissue containing a few (about ten) tetracotyles.

Ducks E and F were kept as controls.

A white rat, bred in the laboratory, was fed with snail tissues containing approximately ten metacercariae with 43 collar spines.

The faeces of ducks and rat were examined daily for eggs. Ducks A and C were seen to be smaller in size than the others at the end of two weeks.

Duck A showed the presence of a few operculated trematode eggs (Fig. 6A) eight days after the feeding. The eggs increased in numbers until it died as a result of an accident 26 days after the infective feed. Post-mortem examination revealed no infection in the lungs or gall bladder but 21 adult echinostomes were present in the caecum and one in the small intestine.

Duck C showed the presence of the same type of eggs as passed by Duck A commencing on the thirteenth day of the infective feed. On the twentieth day a few slightly larger and denser type of trematode eggs were also present. From the twenty-eighth day the number of eggs passed began to diminish and as spontaneous recovery was feared, Duck C was killed and examined for adults. Only one adult of the same type as obtained from Duck A was recovered from the caecum.

Ducks B, D, E and F and the rat continued to remain negative for helminthic eggs in faeces.

Development of Eggs (Fig. 6)

The fresh eggs, which were examined under a coverglass so as to eliminate errors arising from foreshortening, are oval and of uniform size measuring 0.1 by 0.057 mm. The eggs have a refractive smooth thin-wall shell with a yellowish tinge. The operculum is at one end but the slit is faint and difficult to see. At the opposite end the shell shows a slight thickening. In a freshly-laid egg the ovum is a single-celled and prominent globular body measuring about 0.017 mm in diameter and is most often seen at the non-operculated end of the egg surrounded by masses of faintly brown granular balls.

A number of eggs was transferred to some tap water in a petridish and kept in the 29°C incubator. Their development was watched day by day under the microscope by making temporary mounts as hanging-drop preparations. The division of the ovum is rapid and as it develops it seems to move towards the centre. The morula stage is reached in seven days and the development of the miracidium takes sixteen days. The developing miracidium is oval and centrally placed at first but gradually it lengthens until it is longer than the shell when the lower end of the miracidium bends over. It now occupies one side of the egg case, the rest being filled by two large globules of oil-like substance which get pushed about as the miracidium keeps stretching and moving inside the shell case. Under the oil-immersion lens two flame cells can be seen vibrating at about the middle of the body. Near the anterior end can be made out the developing pigment of the eyespots and a granular mass in front of it. The first batch of miracidia to hatch out had taken 24 days.

The Miracidium

The newly hatched-out miracidium is extremely active, swimming rapidly and incessantly by means of the cilia covering the whole of the body. The epidermal cells from which the cilia arise are arranged in four transverse rows of which the cells of the anterior row are the smallest. The miracidia in the living state measure 0.12 mm long and 0.042 mm at the broadest point near the anterior end.

Penetration of Miracidia into Snail Hosts

To a small petri-dish with water containing ten miracidia, a *Lymnaea natalensis* was transferred. This was placed on the stage of a Greenough's binocular microscope and kept under observation. If a miracidium hits the shell it quickly turns round and swims away. If it strikes one of the soft spots it seems to rotate on its long axis as if it was boring into the tissues of the snail. After one or two minutes of this boring motion, it remains quiescent and attached until it is brushed off by the friction against the shell when the snail retracts its body. This brushing off occurred in a few minutes in the case of the miracidia that became attached to the tentacles or head. The miracidia that became attached to the mantle and dorsum of the foot, however, remained fixed and motionless for the twenty minutes during which they were observed. No further attempt was made to study the further penetration and route of migration inside the body of the snail.

As miracidia hatched out they were placed in 3" x 1" tubes with *Lymnaea natalensis*, allowing about half-a-dozen larvae for each snail. These snails were ultimately transferred to jars with well-aerated water in a room at a constant temperature of 22°C and fed on boiled lettuce.

Rediae (Fig. 7)

These same snails died from three to seventeen days after exposure to the miracidia and they were dissected and examined for developmental stages. Only young rediae with undifferentiated germ balls and mother rediae with developing daughter rediae were observed in these. No sporocysts were seen even in the snail which died three days after exposure and no daughter rediae with cercariae were seen even in the snail which had been infected seventeen days. These rediae occupy a superficial position in the digestive gland and when the shell was removed they were seen projecting on the surface and were easily teased out.

The rediae are colourless and capable of some sluggish movement of extension and contraction. The collar, locomotor appendages and the rhabdocoele gut are prominent.

The young rediae are of varying shapes, some being oval, others elongated. They measure from 0.2 mm by 0.12 mm to 0.4 mm by 0.08 mm. The mother rediae with enclosed daughter rediae are also free of pigmentation and measure 0.8 mm by 0.15 mm.

Description of Adults (Fig. 8)

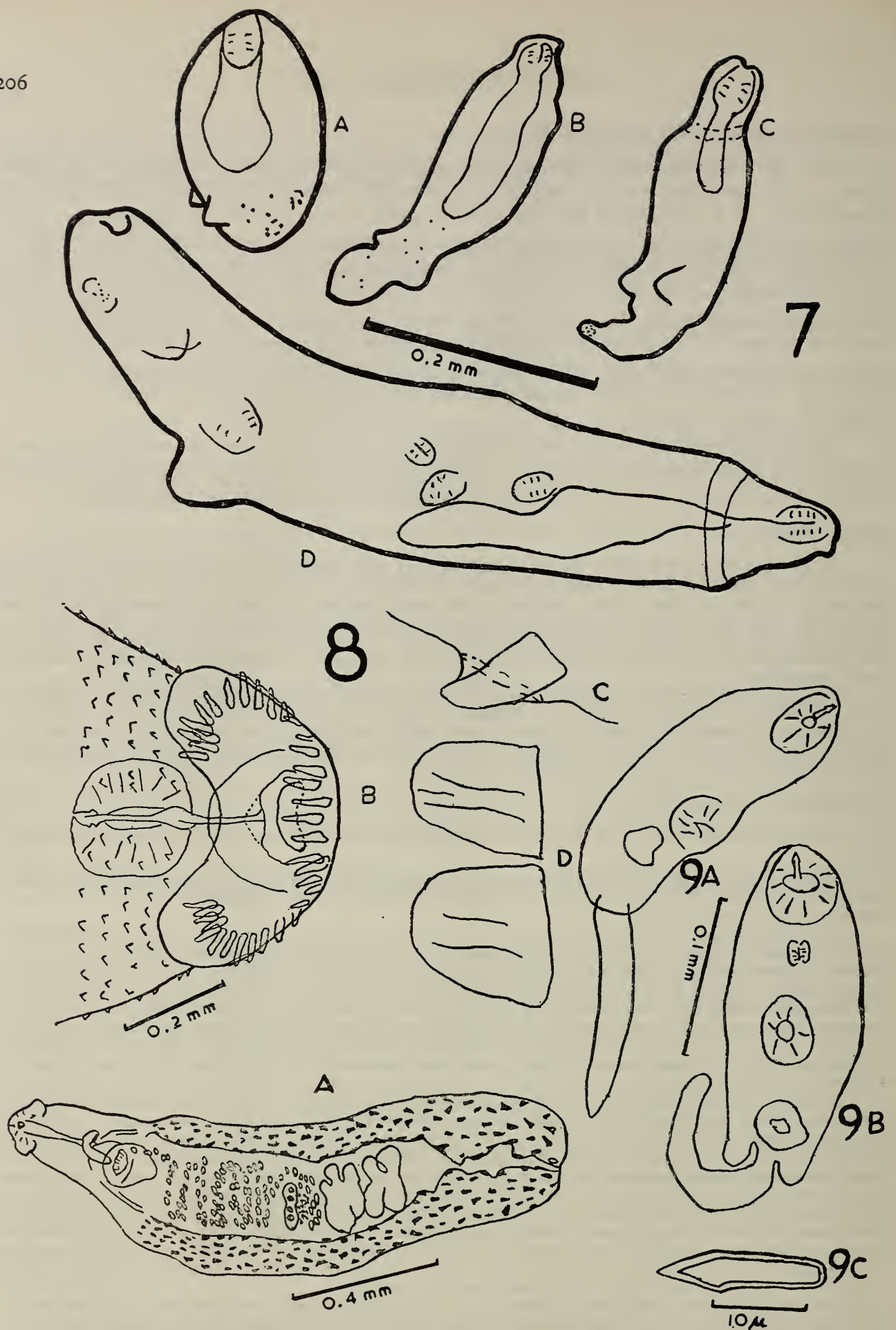
Adults recovered from Ducks A and C proved to be *Echinostoma revolutum* (Froelich 1802), Dietz, 1909.

There was a noticeable difference in the size and stage of development between the single specimen obtained in the small intestine and the twenty-one obtained from the caecum of Duck A, the former being larger and more mature.

The adult has been described previously but Johnson (1920) maintains that Looss, Luhe and others have undoubtedly placed two species, perhaps more, under the name *E. revolutum*. Beaver (1937) shows that the mature worm of this species varies from 4 to 30 mm in length and that the proportionate measurements between the various organs and structures (previously used in species determination) are not constant for all sizes. In addition to *E. echinatum*, which had already been reduced to synonymy, he considers eight others to be synonyms and eight more to be probably synonyms or species of dubious standing. He has emphasised the importance of the number and arrangement of the cephalic spination in the diagnosis of the adult worm. These adults were examined in the light of Beaver's work and the following comments are made.

Although the adults from Duck A are all of same age having been secured 26 days after feeding with metacercariae the specimen from the small intestine is larger and more mature. It measures 15 mm long by 4 mm broad at the widest point, the testes are distinctly lobed and the uterus is a dense mass of transversely coiled tubes packed with numerous eggs. The specimens from the caecum, however, measure only from 5 to 10.2 mm in length by 1.2 to 1.7 mm at the widest point and the uterine coils vary from six to twelve containing 20 to 45 eggs. This finding is interesting in view of the statement of Sandground and Bonne (1940) that the marita of *E. lindoensis* grows to more substantial proportions, especially in width, and that the testes are almost invariably deeply lobed. The findings of eggs in the faeces of Duck A as early as the eighth day is probably due to the quicker development of the adult in the small intestine. It is possible that the more rapid development of the one in the small intestine was due to the ready availability of digested food there as compared with the caecum.

The collar spines number 37 in 19 out of the 22 specimens and 36 in two specimens; one specimen is too badly damaged to allow the counting of spines accurately. In both those specimens with only 36 spines, one of the corner spines has become detached. The arrangement of the collar spines is, as Beaver first pointed out, in the (3+2)+(0+6)+(8+7)+(6+0)+(2+3) fashion.



7. Rediae of *Echinostoma revolutum* in *Lymnaea natalensis*
A-C, young rediae; D, mother redia.

8. Adults of *Echinostoma revolutum* recovered from ducks
A, ventral view; B, ventral view of anterior end; C, side-view of cuticular spine; D, front-view of cuticular spines.

9. *Cercaria malayi* V
A, side view of xiphidocercaria; B, ventral view of same; C, stylet.

Cuticular spines are present on both the dorsal and ventral surfaces in 15 out of the 22 specimens; in the others the spines are evident only on the ventral surface. In some specimens the spines on the dorsal surface extend as far back as the posterior border of the posterior testes. The spines behind the level of the ventral sucker become progressively smaller and more widely spaced till they disappear. Sprehn (1932) and Ben Dawes (1946) consider that *Echinostoma* differs from *Echinoparyphium* in the absence of dorsal cuticular spines. However, Tubangui (1932) and Beaver (1937) mention the presence of cuticular spines on the dorsal surface of *Echinostoma revolutum* although the latter finds in his series that the dorsal cuticular spines are lost after reaching a length of about 8 mm. in ducks and bird hosts.

It was noticed that in the adult worm the cuticular spines (Fig. 8C and D) tend to be more scale-like with a longitudinal thickening and not so sharp-pointed as illustrated by Johnson. Seen in profile, as the spines on the sides appear *in toto* mounts, they are more spine-like with blunt rounded points. In the area between the two suckers they measure 27μ long by 22μ wide.

The testes are oval or slightly lobate with smooth outline. The larger specimen was flattened between two glass slides and fixed and it was noted that the lobulation of the testes which was not evident in the living specimens became noticeable.

SECOND BATCH OF SNAILS

On 17th August, 1949 a second batch of 25 *Lymnaea crosseana* was received four days after it had been despatched by plane from Malaya. All were found dead on arrival.

Dissection of Snails

On dissection eleven snails were found to contain globular metacercariae in numbers varying from about ten to twenty. Some were very dense, others translucent and obviously dead.

On examination, these metacercariae proved to belong to the Echinostome group with about 50 or more collar spines in two rows and therefore different from the two species seen previously. The cysts are provided with a double thick wall which measure 11μ across. The outer wall is wider and more transparent than the inner wall which is dark and thin. The outer wall breaks off readily but the inner wall is tough and it is difficult to rupture it without injuring the contained agamodistome. The metacercaria appears dense and the collar spines cannot be counted accurately. The diameter of the cyst is 0.15 to 0.16 mm.

Feeding Experiments

These metacercariae were fed to one duckling, two rats, two mice and one guinea-pig. None of them became infected judging by the examination of faeces and subsequently of the gut when they were killed one by one after the sixth week.

THIRD BATCH OF SNAILS

On 20th August, 1949, a third batch of snails arrived by air from Malaya. They had taken five days in the travel and consisted of six *Lymnaea crosseana* and two *Planorbis exustus*. Of these only three *Lymnaea* and one *Planorbis* were alive.

Dissection of Snails and Feeding Experiments

The dead snails were dissected and Echinostome metacercariae were present in both species of snails but there were no rediae or sporocysts. Examination of a few metacercariae from each of the snails showed that they all belonged to the 37 collar-spine variety. They were divided into two lots and one was given to a duck and the other portion to a rat.

A month later both animals were killed and examined. The rat was negative but the duck had one *Echinostoma revolutum* in the large intestine.

Description of Xiphidocercariae (Fig. 9)

Of the live snails, one *Lymnaea* discharged a few xiphidocercariae with a stylet. These are poor swimmers being found mostly at the bottom of the glass container. When swimming the body is doubled up ventrally while the tail lashes in all directions. On a glass slide they are capable of crawling with the aid of suckers.

They are distomes with a straight tail which is narrower than the body. Eyes are absent. The anterior extremity is rounded and provided with a stylet which is about 19 to 22 μ long. It has a single needle-like point and has a lateral thickening about a third of the way behind its tip. The stylet lies dorsal to the oral sucker in the long axis of the body. The body is about 0.09 mm in length and about 0.08 mm in maximum width which is at the level or slightly in front of the ventral sucker. The tail is about 0.14 mm in length and 0.023 mm in width. There are no fin folds to the tail.

The ventral sucker which is smaller than the oral, is just behind the middle of the body. The cuticle is spinous being particularly dense in the anterior part of the body. A pharynx is present about midway between the two suckers. The interior of the body is filled with uniformly rounded cells and a little anterior to the side of the ventral sucker are seen two pairs of penetration glands. The excretory bladder is of the simple bicornuate type with a median extension down the tail.

Dissection of Snail discharging Xiphidocercariae

The *Lymnaea crosseana* discharging xiphidocercariae died and dissection showed the presence of cysts and cercariae in elongated sporocysts in the digestive gland. The cysts are oval in shape measuring 0.16 by 0.12 mm and contain an extruded stylet of the same type as above. There is a mass of dark substance close behind the ventral sucker. The agamodistome released from the cyst wall was similar to the one described earlier from the first batch of snails.

Exposure of Snail to Xiphidocercariae

A number of these xiphidocercariae freshly released were placed in the same tube with three *Lymnaea natalensis*. There was a reduction in the numbers of the cercariae and dissection of the snails, all of which had died in the course of two weeks, showed two with metacercariae with extruded stylets.

Dissection of Planorbis exustus

The two snails on dissection showed the presence of Echinostome metacercariae of the 37 collar spine type and presumably of *E. revolutum*. The live snails not discharging cercariae died within 10 days and dissection of these showed no larval trematodes.

SUMMARY

This can only be considered as a preliminary study of some Malayan larval trematodes. The snails had been sent for while the author was working in London in order to study in greater detail the dermatitis-producing *Cercaria malayi* I which had been described earlier. Its absence in these batches of snails sent from the same locality may suggest a seasonal prevalence of infection.

A high incidence of infection of *Lymnaea crosseana* and *Planorbis exustus* exists and a high mortality takes place during the transport of these by air.

The occurrence of mixed infections in these snails is noted, two snails discharging an echinostome and a furcocercous cercaria and one snail discharging two species of echinostome cercariae.

The experimental infections have been, on the whole, unsatisfactory. The inadequate numbers of metacercariae used and the doubt as to their ability to infect should be taken into consideration in interpreting the negative findings.

The identity of the cercaria with 37 collar spines has been established as *Echinostoma revolutum* by experimental feeding of ducks. The development of the egg and the formation of mother rediae in *Lymnaea natalensis* are described.

The morphological studies have been incomplete owing to lack of material but as a preliminary measure these larval trematodes are named as follows :

Echinostome cercariae with 43 collar spines from	
<i>L. crosseana</i>	<i>Cercaria malayi</i> II
Echinostome metacercaria with 50 or more collar spines	
from <i>L. crosseana</i>	<i>Cercaria malayi</i> III
Furcocercous cercaria belonging to the "Strigea" group	
from <i>L. crosseana</i>	<i>Cercaria malayi</i> IV
Xiphidocercaria with stylet from <i>L. crosseana</i> ...	<i>Cercaria malayi</i> V

There has been no difficulty in identifying the "Echinostome" cercariae and the Xiphidocercaria with their respective metacercariae but there is no direct evidence to show that the tetracotyles obtained from the Malayan *Lymnaea* are the later stages of the furcocercous *Cercaria malayi* IV

It has been shown that *L. natalensis* readily acts as first and second intermediate host for *Echinostoma revolutum*, second intermediate host for the echinostome *Cercaria malayi* II and the styleted xiphidocercaria, *Cercaria malayi* V but not as second intermediate host for the furcocercous strigeate, *Cercaria malayi* IV.

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MALAYSIAN PARASITES XIV

WORM INFECTIONS OF SOME MALAYAN ABORIGINES

By

A. A. SANDOSHAM

The Malayan Aborigines fall into three groups, (1) the woolly-haired Negritos, Pygmy Blacks or Semang, (2) the so-called proto-Malay or Jakun and (3) a short, wavy-haired less Mongoloid people called Sakai or Senoi. Many groups are of mixed origin, the mixture sometimes including all three elements. The Negritos are to be found mainly in Kedah, Trengganu and Kelantan, the Jakun in Negri Sembilan and Johore, and the Sakais in Pahang and Perak. According to the 1947 census, they number 34,734 of whom 29,648 are "nomads". The biggest number is in Pahang where there are 13,173 of whom 12,643 are nomadic. These estimates are all probably very low (Willams-Hunt 1952).

The Sakai or Senoi (about whom the present survey is concerned) speak Mon-Khmer dialects and live mainly in the mountains and foothills of the main range and when conditions are favourable come down to the low country. According to Cole (1945) the most generally encountered settlement consists of 2 or 3 houses of closely related individuals placed in a small clearing. A few hundred yards away will be another similar grouping, until finally the settlement will extend for a considerable distance along a water course. Smaller units also occupy hillside clearings. Dwellings usually consists of one room with floors raised high above the ground on piles, with roof of thatch and sides of bamboo.

Rice and millet are replaced when the soil in the clearing gets poorer by sweet-potatoes or bananas and after 3 or 4 seasons it is abandoned and the group moves on. A few chickens, pigs, pet monkeys or birds are seen in most settlements and dogs, unlike in Pygmy or Malay households, are real pets. Aside from work in the fields, the man's chief occupation is hunting and fishing.

Aborigines in Pahang

Early in 1948 there was an outbreak of small-pox among the Senoi in Pahang and the Health Department had organised in April vaccination parties to camp along the banks of the Pahang River to gain access to the Senoi. The writer is grateful to Drs. McGarhity and McLintock and Che Dom for assistance in securing faecal samples from the Senoi. It was very difficult at first to persuade them to part with some of their faeces but 117 of them overcame their superstitious beliefs when bribed with headache balm, tobacco and salt. The specimens were obtained from Nenasi, Pekan, Maran, Ulu Mentiga, Sungei Kertan and Ulu Paleh Inai in Pahang. Owing to the difficult journey involved and the uncertainty of the time that may be taken for samples to arrive at the Kuantan Hospital for examination, it was decided to add 5 per cent. formalin to the faeces on receipt. (Results tabulated overleaf).

A noticeable feature was the extreme lightness of the hookworm infection in most cases. Although no egg-counts were made the paucity of hookworm eggs in the stools was very obvious to the writer who was simultaneously examining faeces of children in Kuantan which were thus available for comparison. One possible explanation would be that the nomadic life of the Aborigines prevents heavy pollution of soil. It may also be due to the hookworms of the Senoi belonging to a different species or variety from the common human forms, with a lower egg-output. This seems unlikely because the same relative fewness of eggs was observed with *Ascaris* infection among the Senoi. Probably associated with this was the frequent finding of unfertilised eggs of *Ascaris*. In 13 out of the 90 positive cases of *Ascaris* infection only unfertilised eggs were seen and in 10 others both fertilized and unfertilized eggs were present.

The results of the examination are summarised below :

					Over 15		1-15		Total	Percentage
					M	F	M	F		
No. examined	...	...	...	...	47	26	22	22	117	—
Hookworms	...	...	...	...	21	13	12	11	57	49
<i>Ascaris</i>	...	...	...	...	36	20	19	15	90	80
<i>Trichuris</i>	...	...	...	...	6	7	7	9	29	24
<i>Enterobius</i>	...	...	...	...	—	—	1	—	1	
<i>Strongyloides</i>	...	...	...	...	—	1	—	—	1	
<i>Dipylidium caninum</i>	...	...	...	...	—	—	—	1	1	
<i>Rhabditis hominis</i> (adults)	...	...	...	...	—	—	—	1	1	
<i>Heterodera</i> sp.	...	...	...	...	—	1				

There were no eggs of *Taenia* sp. in the faeces but Mr. Hayter, the Protector of Aborigines in Malaya, assured me that on two occasions Aborigines carried to him at the end of a stick tapeworms that had been passed by them. They looked fleshy and white and were as long as a man's height.

None of the 50 or so Aborigines the writer saw had any signs of elephantiasis but the laboratory assistant at Pekan Hospital showed the writer a blood film with *Microfilaria malayi* said to have been obtained from a Senoi from Nenasi by the Hospital Assistant in charge of the Travelling Dispensary. The latter asserts that there are cases of elephantiasis of the leg among the Aborigines living along the river banks to the south of Pekan. Green (1932) in the course of blood-film examinations for malaria parasites from Aborigines behind Killinghall Estate came across five with microfilariae but the species was not determined. Poynton and Hodgkin (1938) found a *Microfilaria bancrofti* in an Aborigine-Malay in the Ayer Danak reserve.

Aborigines in Selangor

The writer had arranged to visit a small Aboriginal reserve in the district of Ulu Langat near Kajang in Selangor but was unable to do so. Dr. E. Jumeaux kindly examined the faecal specimens brought from there and reports as follows :

					Over 15		1-15		Total
					M	F	M	F	
No. examined	...	...	...	...	5	2	2	5	14
Hookworms	...	...	...	...	1	—	—	1	2
<i>Ascaris</i>	...	...	...	...	—	1	—	1	2

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MALAYSIAN PARASITES XV

SEVEN NEW WORMS FROM MISCELLANEOUS HOSTS

By

A. A. SANDOSHAM

Parasitic worms from various hosts were received before regular collections were started by the Colonial Office Research Unit. The following seven of these are here described as follows :

- A male Gordiid worm said to have been from man
- Paragonimus macacae* n. sp. (Troglorematidae) from a monkey
- Setaria thomasi* n. sp. (Filariidae) from a wild pig
- Setaria javensis* Vevers, 1922 (Filariidae) from a mouse-deer
- Gnathostoma doloresi* Tubangui, 1925 (Spiruridae) from a pig
- Proleptus malayi* n. sp. (Physalopteridae) from a dogfish
- Africana singaporensis* n. sp. (Heterakidae) from a toad

A Male Gordiid worm said to have been passed *per anum* by a Malayan patient

The specimen was in the collection of the Department of Biology of King Edward VII College of Medicine, Singapore, with a slip of paper in the specimen tube with the following legend : " Passed *per anum* by patient at Kampar Hospital, September 1930." Parasitological oddities in Malaya have a way to trickling down to the Department of Biology in Singapore and it is not improbable that the information contained is correct. It is possible that the specimen did not excite the curiosity it deserved and was set aside because there was no one in the department competent to report on it at that time. If this assumption is correct, this case in Malaya is added as yet another record of the rare parasitisation of man by a Gordiid worm.

Description (Fig. 1)

The specimen is an elongated opaque dark brown worm, measuring 31 mm in length and 1.5 mm in diameter. The anterior end is more or less rounded, with two lip-like structures bordering the mouth. No lateral lines are seen. The cuticle from the middle of the worm appears smooth without areoles in lacto-phenol solution. The posterior end is bifurcated behind the anus. A post-anal crescent is well developed. In view of the above characters, it is considered to belong to the family Gordiidae Diesing of the Nematomorpha. As pointed out by Baylis (1943), the nomenclature and determination of this group have become a matter of great complexity and the writer does not feel competent to express any opinion beyond assigning it to the only genus in the Family, *Gordius* sensu stricto.

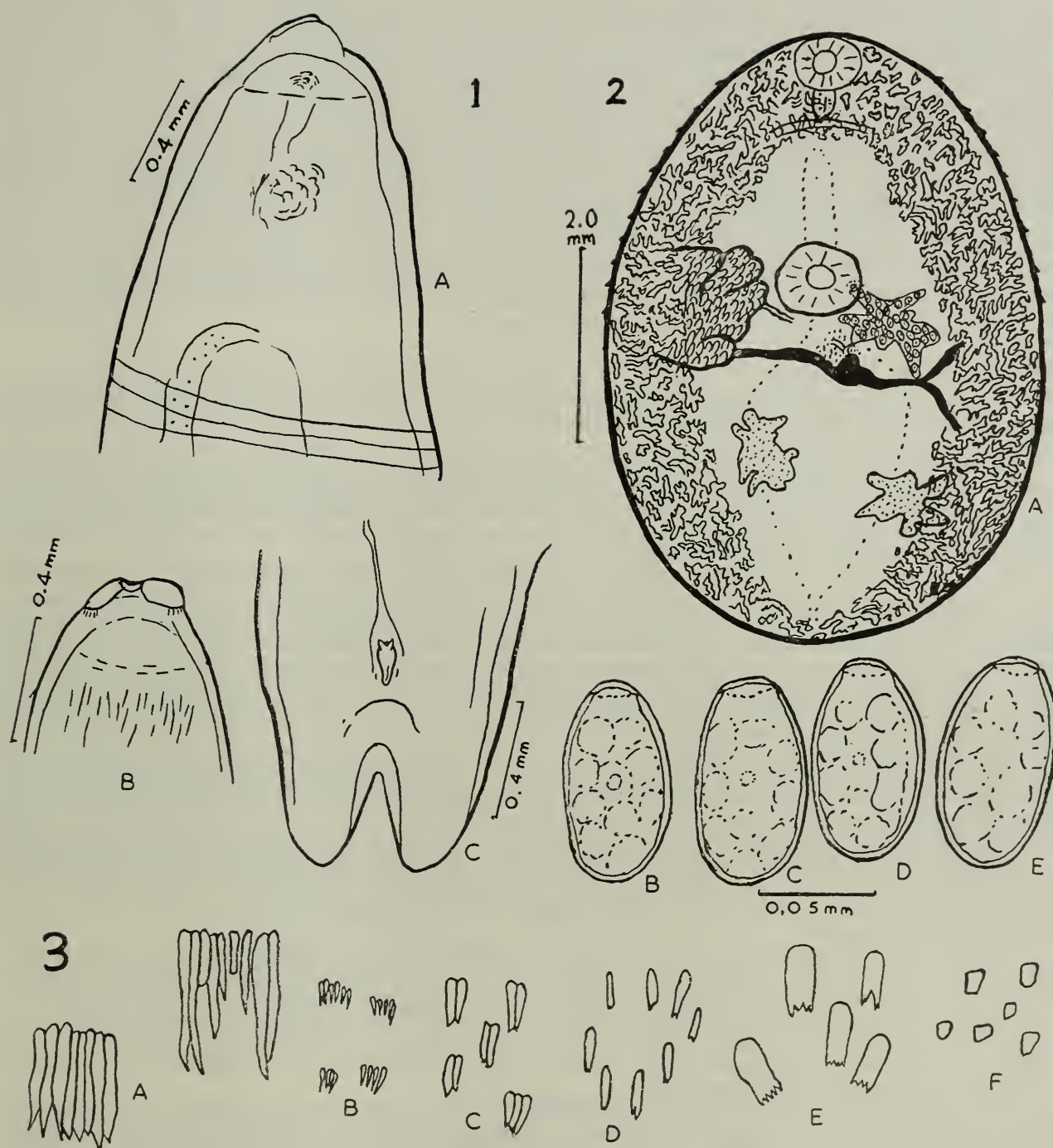
Twenty-three cases of 'parasitism' by Gordiacean worms are recorded in man, none of which is from Asia. Of these, only seven belong to the Family Gordiidae and Sayad *et al.* (1936) believe that their case report is the only authentic record of accidental parasitism by a gordiid worm in man.

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***Paragonimus macacae* n. sp. from a monkey**

One of the long-tailed or so-called crab-eating macaques (*Macaca irus* Cuvier) used for experimental purposes at what was then the King Edward VII College of Medicine, Singapore, died and the post-mortem examination revealed the presence of many lung flukes belonging to the genus *Paragonimus* Braun, 1899.



1. *Gordius* sp.

A, lateral view of head; B, ventral view of head; C, ventral view of tail.

2. *Paragonimus macacae* n. sp.

A, ventral view; B-E, eggs.

3. *Paragonimus* spp., cuticular spines from area between suckers

A, *P. ohirai* (after Chen); B, *P. compactus* (after Vevers); C, *P. iloktsuenensis* (after Chen); D, *P. westermani* (after Vevers); E, *P. kellicotti* (after Vevers); F, *P. macacae* n. sp.

Technique for the Study of Spines

Particular attention was paid to the cuticular spines since some authorities consider their size, shape and arrangement are of great value in species determination. It was found that the spines appeared more refractive when cleared in clove oil than when creosote was used. Entire mounts were not very satisfactory for the study of cuticular spines. Even when the ventral wall was sliced out with a razor and the internal structures were scraped out before mounting, the preparation was not altogether satisfactory as it tended to present an oblique or an *en face* view of the spines. The best appearance of the shape and arrangement of the spines was obtained by softening the cuticle by leaving overnight in ten per cent caustic soda and applying pressure on the coverglass to flatten out the spines. The variations in the appearance of spines produced by the different methods of preparing the specimen for examination probably account, in some degree, for the confusion and uncertainty on the value of spines as diagnostic features in this difficult genus.

Description (Figs. 2 and 3)

The body is plump and shaped like a coffee-bean with a flat ventral and a convex dorsal surface. It measures about 6 to 7 mm in length and its maximum width, which is near the middle of the body, is about 4.5 to 5 mm.

The oral sucker, which is terminal or sub-terminal in position, is 0.75 mm in diameter. The ventral sucker is just in front of the middle of the body in the midline, is rounded and has a diameter of 0.8 to 0.9 mm. There is a rounded pharynx measuring about 0.2 mm in diameter which leads into a very short oesophagus. The latter divides into two broad irregularly wavy intestinal caeca which run along the lateral edges of the fluke to its posterior end.

The cuticular spines are deeply embedded and are best seen on the ventral surface in the interval between the two suckers and between the testes. Various workers have shown that for practical diagnostic purposes one should concentrate on the more typical spines in these two areas. The spines on the ventral surface between the two suckers in this species are not very different from those in the region between the two testes. The spines are single and somewhat cylindrical and not much longer than broad. The free edge on side view looks rounded with one or two shallow notches. The *en face* view of the free edge appears dimpled in many spines. These singly spaced spines are in closely set irregular rows, the individual spines being about 6 to 20 μ apart.

The excretory canal from near the posterior extremity in the median plane runs for a distance of about 0.6 mm before it dilates into a large pyriform sinus. The latter narrows considerably at about the level of the ventral sucker but extends forwards up to the oesophageal region. The details of the terminal branches and the flame cell system could not be made out.

The two testes are now more or less symmetrically arranged towards the dorsal side in the third quarter of the body partially overlapped by the vitellaria. The testes are irregularly lobed with finger-like processes arising from a central mass. The vasa efferentia run forwards and medially close to the dorsal surface and meet to form a seminal vesicle which lies immediately posterior to and slightly to the right of the ventral sucker.

The ovary lies to the left of the median plane in a dorsal position at about the level of the ventral sucker. It is a dense lobed structure with one or two of the lobes prolonged into finger-like processes. The oviduct is connected to the large yolk reservoir and the ootype is surrounded by the shell gland.

The uterus, filled with eggs, is a highly coiled organ occupying nearly the entire lateral portion of this region to the right of the mid-line. Towards the terminal portion the uterus narrows down to form the metraterm which runs medially and opens into the common genital atrium. The genital pore is posterior to the ventral sucker in the median plane.

The operculated yellowish-brown eggs squeezed out of the flukes measure, under a coverglass with plenty of water below, 85 to 92 μ by 45 to 48 μ . Each egg is typically oval and symmetrical with the maximum width about the middle. The shell has a uniform thickness with a slight general thickening at the non-operculated pole.

The vitelline glands are profusely branched. They are marginal extending the whole length of the body and overlapping the gut branches. The median open space is larger on the ventral than on the dorsal side. The large transverse vitelline ducts, formed by the fusion of the two longitudinal ducts on either side, meet near the midline posterior to the level of the ventral sucker to form a large pear-shaped reservoir which opens into the oviduct.

Discussion

The identity of the different species of *Paragonimus* is still an unsettled question. It is generally recognised that variations in adult morphology in any single species of *Paragonimus* are too great to be much value in species determination.

Ward and Hirsch (1915) first emphasized the value of cuticular spines in species determination and Vevers (1923) confirmed their findings. Ameel (1934) who presents some evidence to indicate that the cuticular spines of the adult may not be good criteria for differentiation of species of *Paragonimus*, nevertheless concludes as follows: "For the present, in the absence of conclusive evidence either to support or contradict the work of Ward and Hirsch, it is believed advisable to recognise the species considered valid by them, namely, *Paragonimus westermani*, *P. ringeri*, and *P. kellicotti*. Likewise, *P. compactus*, recognised as a distinct species by Vevers, should be retained until it can be restudied." Chen (1940) showed that the differentiation of spines of *P. iloktsuenensis* came very early during the growth period of the adult life and from the second month on only slight changes took place. He also showed that the shape and arrangement of spines on specimens obtained from various experimental animal hosts remained constant. These facts point to the value of cuticular spines in species determination.

Miyazaki (1939) and Tang (1940) point out that more taxonomic characters may be found through the observation of the developmental larval stages of the parasite. Chen (1940) from an exhaustive comparative study of the various species of *Paragonimus* concludes that *P. ringeri* and *P. edwardsi* are synonyms of *P. westermani*. He recognises *P. westermani*, *P. kellicotti*, *P. ohirai*, *P. compactus*, and *P. iloktsuenensis* as distinct species. He maintains that characters such as the egg shell (irregular or regular in thickness), the cuticular spines of the adult, the number of walls (one or two) of the metacercaria, and host specificity should be regarded for the present as the most important differentiating features.

The shape, form and arrangement of the cuticular spines in this species would serve to place it in the *westermani-kellicotti* group and not in the *compactus-iloktsuenensis-ohirai* group. The typical spines, however, are somewhat different from those of *P. kellicotti* in which the free edge is deeply serrated with a saw-toothed appearance. It differs from *P. westermani*, in which species the typical spines are narrow and long and the egg shell is irregular in thickness. The monkey is a new host for *Paragonimus*. For these reasons it seems desirable to regard it as a new species pending confirmation or otherwise by a more extensive study of the cuticular spines of *Paragonimus* species, and of life-history studies for morphology of larval forms, as well as experimental infection of laboratory animals to determine the degree of host-specificity.

Family : *Troglotreematidae* Odhner, 1914

Genus : *Paragonimus* Braun, 1899

Species : *P. macacae* n. sp.

Host : *Macaca irus irus* Cuvier

Habitat : Lung

Locality : Malaya

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Setaria thomasi n. sp. from a wild pig.

Five female and three male worms were obtained from the peritoneal cavity of a wild boar (*Sus scrofa jubatus* Miller) shot in Kelantan, Pahang, Malaya by Mr. P. V. Thomas, Veterinary Officer, after whom it is named. These worms are referable to the genus *Setaria* Viborg, 1795 and are considered to represent a new species.

Description (Figs. 4 and 5)

The body is filiform tapering towards the posterior extremity which is twisted into a loose spiral especially in the females. The anterior end is rounded, the mouth being surrounded by a thick oval chitinous "peribuccal ring." Four submedian cephalic papillae and a pair of smaller lateral papillae are seen. Cuticular striations are not evident and the cervical papillae are not seen.

The Male: The male measures from 48 to 57 mm in length and 0.4 mm in maximum thickness. The nerve ring is 0.22 to 0.26 mm behind the anterior extremity. The anterior muscular portion of the oesophagus is 0.54 to 0.57 mm in length and the posterior glandular portion is 9.3 mm in length. The tail is 0.8 mm long and its tip is rounded. The spicules are unequal and dissimilar. The left spicule is longer and consists of a proximal tubular chitinous portion measuring 0.16 to 0.17 mm in length and a distal portion, partly membranous and partly thread-like of somewhat indeterminate length. The right spicule whose terminal portion is not so heavily chitinised measures 0.08 to 0.09 mm in length.

Fourteen pairs of caudal papillae are present, seven pairs being pre-cloacal in position. The arrangement of the papillae is seen in Fig. 33.

The Female: The female measures from 54 to 95 mm in length and 0.6 mm in maximum width. The nerve ring is 0.2 to 0.28 mm. from the anterior extremity. The anterior muscular portion of the oesophagus measures 0.54 to 0.62 mm in length and the posterior glandular portion 10 to 10.6 mm in length. The tail, which is coiled more than in the male, has a button-like tip close to which is a pair of small papillae. The vulva is situated at a distance of from 0.26 to 0.44 mm from the anterior end of the body. It leads through a muscular ovejector to a vagina which runs posteriorly into a common uterine trunk. The egg measures 37 by 19 μ and contains a coiled larva.

Discussion

Thwaite (1927) gave a useful review of the species which might be assigned to the genus *Setaria*. Since then the following have been added to the list : *S. tundra* Issatschekow and Rajewsky, 1928. *S. altaica* Rajewsky 1928 (considered a synonym of *S. cervi* by Baylis), *S. loveridgei* Sandground, 1928, *S. hyracis* Baylis 1932, *S. buxi*. Bhalarao 1933 (considered a synonym of *S. cervi* by Baylis), *S. thwaitei* Monnig 1933, *S. sandersoni* Baylis 1936, *S. rodhaini* Berghe and Verylsteke 1936, *S. leichingwingi* Chen 1937. By reason of the number and arrangement of the caudal papillae in the male, this species can be easily distinguished from the known species of this genus.

It is interesting to note that so far only three other species of *Setaria* have been recorded from Suidae, namely *S. congolensis* Bailliet and Henry 1911 from *Phacochoerus porcus* in the French Congo, *S. bernadi* Railliet and Henry 1911, described by Bernard and Banche (1910) from the domestic pig in Annam ; and *S. rodhaini* Berghe and Verylsteke 1936 from *Potamochoerus porcus* in the Belgian Congo. Thwaite (1927) makes reference to the unfortunate absence of illustrations of *S. congolensis* and *S. bernardi* accompanying the original descriptions, and expresses the opinion that *S. bernardi* bears a distinct resemblance to the former. Sandground (1933) on the basis of three males obtained from *Sus cristatus* from Annam concludes that *S. bernardi* is identical with *S. congolensis*. Chatterji (1939), however, obtained *Setaria* from the domestic pig in Burma which he considers to be *S. bernardi* and quite distinct from *S. congolensis* or *S. cervi*.

Family : *Filariidae*

Genus : *Setaria* Viborg, 1795

Species : *S. thomasi* n. sp.

Host : *Sus scrofa jubatus* Miller (Wild boar)

Location : Peritoneal cavity

Locality : Pahang, Malaya

References

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***Setaria javensis* Vevers, 1922 from a mouse-deer.**

Although Vevers described this species from *Tragulus "stanleyanus"* (= *T. javanicus*) from Java twenty-seven years ago, there has been no further record of it in literature and the male still remains unknown. Thwaite (1927) says the following in his useful summary of the then known members of the genus *Setaria* Viborg 1795: The description of *S. javensis* is inadequate, and the figure is not sufficiently clear to enable the exact structure of the mouth parts to be determined in detail. The worm could, with advantage, be redescribed and figured.

Recently, a pet mouse-deer or Plandok, *Tragulus javanicus*, belonging to the late Sir Edward Gent, died at Government House, Kuala Lumpur, Malaya and Mr. J. Davie, the Veterinary Officer, in the course of a post-mortem examination found three females and one male *Setaria* in the thoracic cavity. The specimens which had been in normal saline for a few days were somewhat damaged. Examination showed that they correspond closely to *S. javensis* Vevers 1922 and the opportunity is taken to redescribe the female and add a description of the hitherto unknown male. Malaya thus becomes an additional area of distribution.

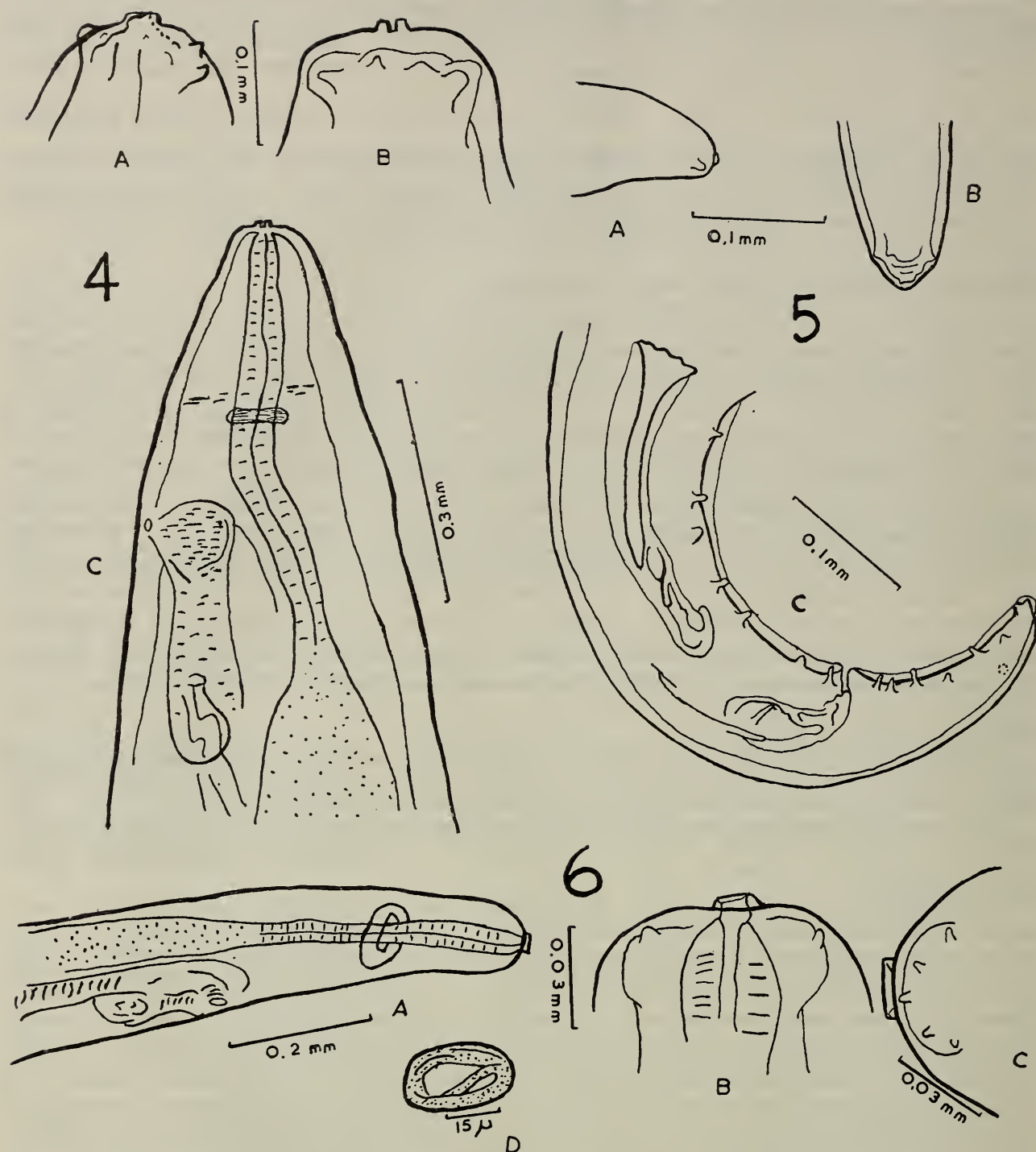
Description (Figs. 6 and 7)

The filiform worms are whitish in colour and taper towards both extremities. The head is rounded and not separated from the rest of the body. The posterior ends of both the male and female worms are slightly coiled. Cuticular striations are not evident and no cervical papillae are seen.

The mouth is surrounded by a simple oval thin chitinous peribuccal ring which is not notched or prolonged anteriorly to form lips. The greater diameter, which measures 22μ , is dorso-ventral in direction, while the lesser diameter measures about 14μ . The head is provided with two lateral and four pairs of submedian papillae.

The females, all of which are gravid, measure from about 50 to 80 mm in length by a little under 0.5 mm in maximum width. The mouth is followed by the muscular part of the oesophagus which has a length of between 0.33 and 0.4 mm; this passes into the thicker and glandular portion which measures 1.7 to 2 mm in length and 0.1 mm in maximum width. The total length of the oesophagus is thus small and compared with the length of the worm, gives a ratio of between 1:22 to 1:24.7. The nerve ring is found at a distance which varies between 0.17 and 0.185 mm from the anterior extremity of the worm. The vulva is situated between 0.4 and 0.45 mm from the head end. It leads through a muscular ovejector measuring about 0.2 mm in length to a muscular vagina 6 mm long. The terminal part of the uterine branches is filled with embryos which measure between 0.12 and 0.2 mm in length and about 7.5μ in width. The egg *in utero* measures 30 to 40μ by 18 to 22μ and contains a coiled larva. Anteriorly, the coils of the genital ducts reach up to the level where the oesophagus ends and posteriorly they extend to within 0.65 mm of the tail end. The anus is situated 0.26 to 0.28 mm from the posterior extremity. The tail tapers gradually and ends in a small knob. No cuticular appendages are present at the tail end.

The single male in the collection measures 32 mm in length by 0.22 mm in maximum breadth. The muscular part of the oesophagus measures 0.35 mm and the posterior glandular portion 1.9 mm. The total length of the oesophagus, compared with the length of the worm, gives a ratio of 1:14.2. The nerve ring encircles the muscular portions of the oesophagus at a point 0.2 mm behind the anterior extremity. The tail is conical in shape and rather blunt. It measured 0.1 mm in length. There are six pairs of caudal papillae of which four are post-anal. In the midline, for a short distance anterior to the caudal papillae, there are a large number of minute bosses on the cuticle. Caudal appendages are not present. The left spicule is about 0.2 mm long and shows the usual division into a tubular proximal portion and a twisted indefinite distal portion. The broader right spicule, which shows a characteristic spur on the ventral edge near the tip, measures about 0.06 mm in length.



4, 5. *Setaria thomasi* n. sp.

4. A, dorsal view of head; B, lateral view of head; C, lateral view of anterior end of female.

5. A, lateral view of tip of tail of female; B, ventral view of tip of tail of female; C, lateral view of posterior end of male.

6. *Setaria javensis* Vevers (see Fig. 7)

A, lateral view of anterior part of female; B, dorsal view of head; C, lateral view of head; D, eggs.

Discussion

The specimens here described conform very closely to the description of *S. javensis* by Vevers. The total length of the oesophagus in his specimens, however, seems to be much larger. This may represent a marked variation of the length of the oesophagus in this species or it may be possible that the vagina was confused with the oesophagus.

References

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Gnathostoma doloresi Tubangui, 1925, from a pig

A male and a female of this species were collected by Dr. Wutherington, the Veterinary Officer, from a pig in Singapore. The pig is said to have been Malayan bred and the specimens were obtained from the liver, which is a very unusual location for members of this genus.

Tubangui (1925) described the female in the pig in the Philippine Islands and Mapleston (1930) described the male from India where he found the species eleven times in the stomachs of forty-nine pigs. Mapleston considers that these worms cause extensive damage to the stomach wall in which they burrow deeply. Mapleston found two distinct sizes of worms in different pigs, the small and large forms never being found together in the same host. Tubangui's measurements for the females, however, came exactly in the gap left between the small and large worms of Mapleston's series.

Description (Fig. 8)

In the Malayan specimens the male is intermediate in size between Mapleston's two forms, and the female, which is not fully mature, is inclined to resemble the smaller variety. Certain other features which are at variance with the descriptions available are noted but, in view of the remarkable degree of variations noted in *G. doloresi*, the Malayan form is not considered a separate species.

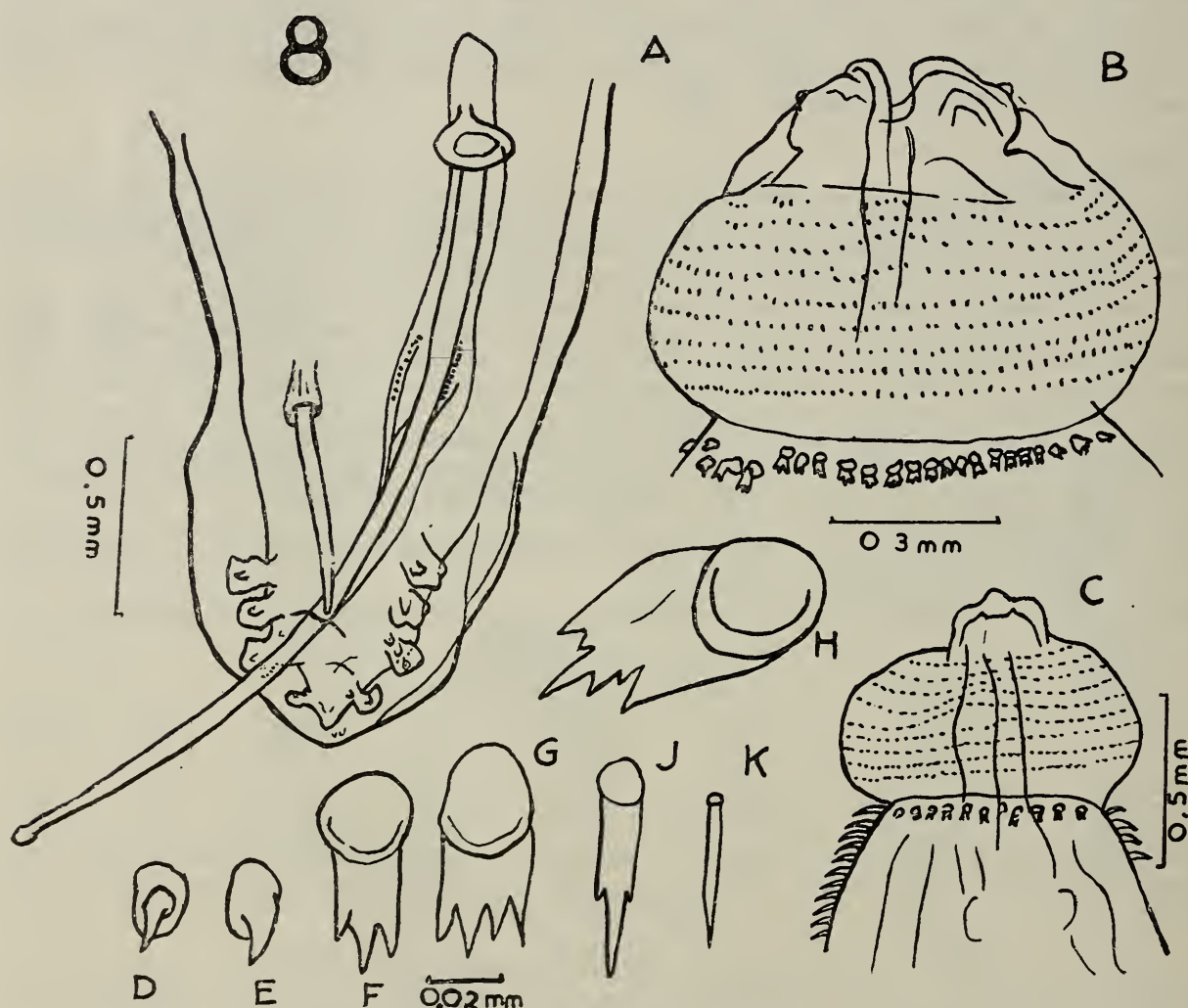
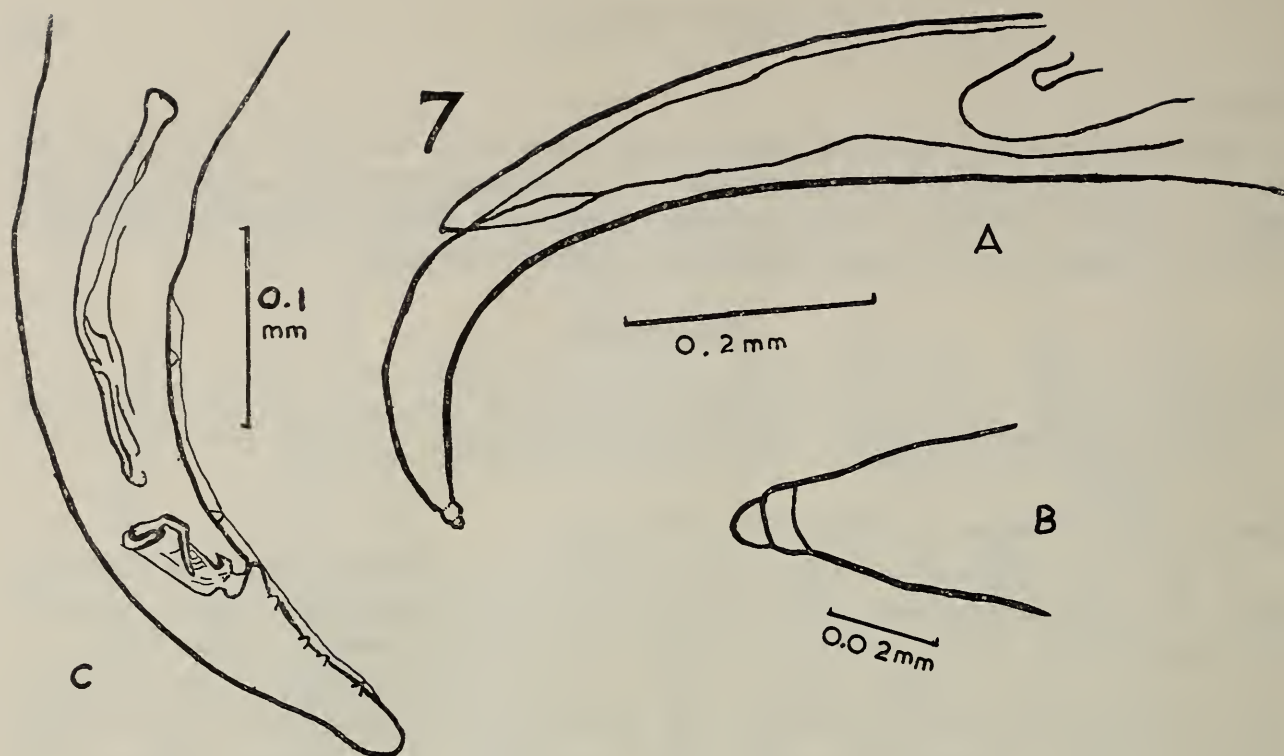
The left spicule in the Malayan form measures 2.68mm in length as compared with Mapleston's 1.85 to 2.08mm. The proximal half of the left spicule is provided with a membranous expansion which is broadest at about one quarter of the distance from the base. Of the four pairs of large caudal papillae two, and not one as described by Mapleston, are pre-anal in position. The head bulb is armed with ten rows of backwardly curving hooks but the most anterior row is incomplete in both the specimens. The body spines are as described by Mapleston but not Tubangui, and no spines with more than six points were seen. As the bases of cuticular spines are considered important it is recorded that the bases of the head bulb are not highly chitinised and are oval in shape, while those on the body tend to be more distinct and circular.

For purposes of comparison, the dimensions for Philippine and Indian forms are given below together with those for the Malayan specimens.

MEASUREMENTS OF SPECIMENS OF *GNATHOSTOMA DOLORESI* FROM VARIOUS SOURCES.

	PHILIPPINES.		INDIA.				MALAYA.	
			Large worms.		Small worms.		Male.	Female.
		Female.	Male.	Female.	Male.	Female.		
Length ...	...	30-31	35-38	43-52	20-21	27-31	24.5	27
Maximum width ...	...	—	1.4-1.66	2.6-2.8	0.9-1.2	1.3-1.5	1.3	1.6
Diam. in inflation ...	...	3.14-3.37	1.7-2.6	2.7-4.9	1.1-1.76	1.46-2.02	1.8	3.26
Head bulb length ...	...	0.4-0.46	—	—	0.317	0.356-0.396	0.4	0.52
Head bulb diameter ...	...	0.75-0.85	0.693	0.891-1.01	0.634	0.772-0.832	0.72	0.85
Nerve ring ...	...	0.75	—	1.38	0.832	1.04	1.0	1.3
Oesophagus ...	...	6-7	—	—	3.9	5.7	3.6	5.2
Vulva to tip of tail ...	...	Behind middle	—	16-19	—	10.4-10.9	—	10.2
Spicule, left ...	...	—	1.85-2.07	—	1.85-2.08	—	2.68	—
Spicule, right ...	...	—	0.64-0.66	—	0.6-0.7	—	0.645	—
Eggs ...	...	0.06-0.063 × 0.037.	—	0.064-0.067 × 0.031-0.034.	—	0.052-0.06 × 0.033-0.031	—	—

MALAYA, No. 26, 1953



7. *Setaria javensis* Vevers (see Fig. 6)

A, lateral view of posterior part of female; B, ventral view of tip of tail of female; C, lateral view of posterior part of male

8. *Gnathostoma doloresi* Tubangui

A, ventral view of posterior end of male; B, dorsal view of head; C, lateral view of head; D, front view of head spine; E, side view of head spine; F-G, front view of body spines; H, spine; thirteenth row; I, spine from about one-fourth length of body from anterior end; J, spine from about middle of body.

References

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***Proleptus malayi* n. sp. from a dogfish.**

Four male and ten female nematodes belonging to the genus *Proleptus* Dujardin, 1845, were obtained from the small intestine of the spotted dogfish *Scyllium* sp. caught in Malayan waters.

Baylis (1933) reviewed what was known of the various species which may be attributed to the genus *Proleptus* and concluded that six species could be recognised with some degree of probability. Since then three other species have been added to the list. The specimens obtained off the Malayan coast differ from these and are here described as a new species.

Description (Fig. 9)

The Male: The male measures approximately 25 to 27.5 mm in length and 0.55 to 0.58 mm in maximum thickness. The cuticular striations are at intervals of about 4.5. The anterior end is surrounded by a cuticular inflation. Each lip, in addition to the median lateral tooth, bears on its inner surface and projecting beyond its rim, two pairs of rather long spine-like teeth, situated subdorsally and subventrally and between these and the median tooth a few small denticles. There are three papillae on each lip. The anterior portion of the oesophagus is 0.6 to 0.62 mm long. The cervical papillae are immediately in front of the nerve ring which is 0.34 to 0.35 mm from the anterior end. The excretory pore opens at a distance of 0.5 to 0.67 from the anterior extremity.

The caudal end of the male is spirally coiled, and the annulations, which are pronounced on the ventral surface, are serrated. The tail is 0.52 to 0.72 mm long and the caudal alae are well developed and symmetrical. There are eight pairs of caudal papillae and a single median papilla. The six anterior pairs, of which three are pre-anal in position, are long and rib-like. The median papilla is large and is situated immediately in front of the cloacal opening.

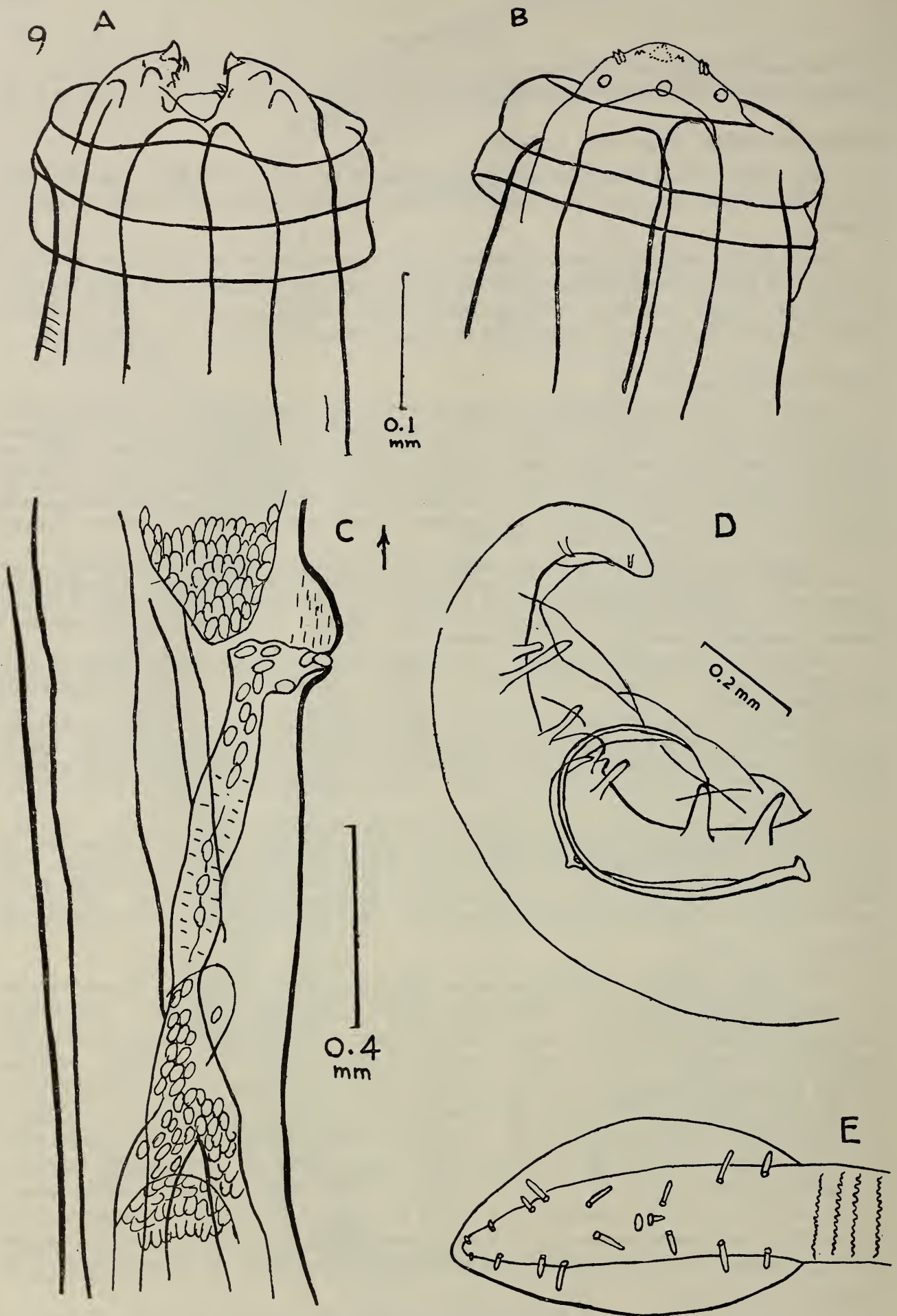
The spicules are unequal and dissimilar. The right spicule is relatively stout and measures 0.185 to 0.23 mm in length. The left spicule, which is provided with an ala, is more slender and measures 0.85 to 0.9 mm in length.

The Female: The female measures 40 to 42.5 mm in length and 0.81 mm in maximum thickness. The anterior portion of the oesophagus is 0.73 to 0.93 mm long, the entire oesophagus being 5.13 to 6.06 mm in length. The cervical papillae are situated at a distance of 0.33 to 0.35 mm from the anterior extremity and the nerve ring about 0.1 mm behind the papillae. The excretory pore opens at a point 0.59 to 0.65 mm behind the anterior end.

The tail of the female is bent somewhat dorsally and measures 0.42 to 0.489 mm in length. The tip of the tail is bluntly rounded. The vulva is situated exceptionally far forward, at 13.6 to 14.34 mm from the posterior end. It opens on the posterior surface of a rounded prominence which appears muscular. The vagina runs posteriorly (anteriorly in two of the specimens). From the vulva and after a course of 1.13 to 1.14 mm gives off the two uterine branches which at first lie parallel to one another. The eggs are provided with thick shells (6 to 7 μ) and contain coiled larvae and measure 0.048 mm by 0.03 to 0.031 mm.

Discussion

The worm described above is considered different from any of the known species. *P. acutus* Dujardin, 1845 differs considerably in size and length of spicules. The original description, which was based on a single male specimen, however, is too brief to allow further comparisons to be made. In *P. obtusus* Dujardin, 1845, the spicules are much longer. Besides, none of the four male specimens of the species described above shows the right angled bend of the tip of the right spicule described by Miller (1925) and considered by Baylis (1933) as "a very characteristic feature of *P. obtusus*." Although *P. inflatus* (v. Linstow, 1890) Baylis, 1933, is a larger worm, its left spicule is only about half the length of the corresponding spicule of the species described here. *P. africanus* (v. Linstow, 1899), Baylis, 1933 can be differentiated by the size of the spicules, tail length and size of the worm. *P. robustus* (v. Beneden, 1871), Seurat, 1916, can be distinguished by the length and appearance of the spicules, the number of caudal papillae in the male and the position of the vulvar opening. *P. australis* Baylis, 1933,



9. *Proleptus malayi* n. sp.

A, lateral view of head; B, dorsal view of head; C, lateral view showing vulva and vagina; D, lateral view of posterior end of male; E, ventral view of posterior end of male.

is a much smaller worm with longer spicules. The relation of the left spicule to the length of the entire worm, for instance, varies from 1/11.7 to 1/13.3 as against 1/29.4 to 1/30.6 in the species described above. Other points of difference include length of vagina, size of egg and numbers of caudal papillae in the male. *P. anabanti* Pearse, 1933 is a much smaller worm with simple lips and a smooth cuticle. *P. problematicus* Kreis, 1940 and *P. trygonorrhinae* Johnson and Mawson, 1943 differ in the length of spicules and oesophagus, in the position of the vulva and in the number and arrangement of the caudal papillae in the male. *P. sordidus* Lent and Freitas, 1948 may be distinguished by the posterior position of the vulva and the attenuated tail in the female and the size of the spicules and the number and position of the caudal papillae in the male.

Family: *Physalopteridae* Leiper, 1908.
 Sub-family: *Physalopterinae* Bailliet, 1893.
 Genus: *Proleptus* Dujardin, 1845.
 Species: *P. malayi* n. sp.
 Host: *Scyllium* sp.
 Location: Small intestine.
 Locality: Sea-coast, Malaya.

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Africana singaporensis n. sp. from a toad.

These worms were obtained from the large intestine of the toad, *Bufo melanostictus*, collected in Singapore.

Description (Fig. 10)

The Male: The male measures 5.2 to 5.7 mm in length and its maximum width which is at about the middle of the body is 0.28 mm. There are three well-developed lips with the apices of their free margins prolonged into anteriorly directed cuticular processes. Each of the lips bears two submedial rounded papillae. The diameter of the head at the base of the lips is 0.05 to 0.06 mm. Cervical papillae are absent and the lateral cuticular flanges are feebly developed. The oesophagus, including the pharynx and bulb, measures 0.88 to 0.9 mm in length. The pharynx is 0.063 mm long and 0.026 mm broad. The oesophageal bulb is 0.17 mm long and 0.15 mm broad. The excretory pore is 0.49 mm from the anterior end and communicates with a large excretory vesicle. The nerve ring is 0.26 mm from the anterior end.

The preanal sucker is somewhat oval, being 0.05 mm long and 0.04 mm wide. The tail, which is conical, is curved ventrally and is 0.26 mm long. The caudal alae are membranous and extend from a point about 0.4 to 0.5 mm from the tip of the tail to a short distance beyond the level of the cloacal opening. At the widest point, the caudal alae stretch on either side of the body for about 0.04 to 0.08 mm. In most specimens the caudal alae merge into the lateral wall of the body and even in those in which their outline extends ventrally, the alae do not meet in the midline.

Twenty-two pairs of caudal papillae are present, of which three are pre-suctorial in position, three para-suctorial, five between the sucker and the cloacal opening and the rest post-anal. Of the presuctorial group of papillae, the two anterior ones are sub-ventral and the posterior one slightly more lateral in

position. All three pairs of para-suctorial papillae are ventro-laterally placed, the two anterior pairs being very stout. Of the five pairs of papillae between the sucker and the cloacal opening, the first and the last are small and sessile and sub-ventrally placed, while the other three are long and slender and more laterally situated. A little behind the level of the cloacal opening and lateral in position is a pair of large fleshy papillae. Slightly medial to these is a pair of minute papillae which are not seen in all specimens. Another pair of small subventrally placed papillae is sometimes seen immediately behind the cloacal opening. There are two pairs of papillae at the level at which the tail bends ventrally, the larger pair occupying a more lateral position. There are three pairs of small papillae which are somewhat clumped together sub-ventrally near the tip of the tail. There is also a single dorsal pair near the tip of the tail.

The spicules are equal and similar and measure 0.74 to 0.96 mm in length, the average of ten measurements being 0.837 mm. The spicules, except for the terminal millimetre, appear stout owing to the presence of a sheath with a ventral gutter and a tessellated surface. The spicules taper suddenly at the terminal portion and end in a blunt point.

The Female: The female measures 6.52 to 7 mm in length and the maximum width which is at about the middle of the body is 0.33 mm. The oesophagus, including the pharynx and bulb, measures 1.14 mm. The pharynx is 0.074 mm long and 0.03 mm broad. The oesophageal bulb is 0.2 mm long and 0.17 mm broad. The nerve ring and the excretory pore are 0.35 mm and 0.59 mm from the anterior extremity respectively. The tail is straight and tapers gradually to a point and is 0.36 mm long.

The vulva, which in most specimens is provided with a posteriorly-directed flap, opens at a point 2.7 to 2.9 mm from the anterior end. The vagina, which is 1.9 to 2 mm long, is muscular and runs posteriorly in a somewhat zig-zag manner and ends in two uteri which are apparently opposed, being parallel to one another only for a distance of about 0.4 mm, after which one branch doubles back upon itself and runs in the opposite direction. The eggs are oval and provided with a thick smooth shell and measures 0.077 to 0.043 mm. The eggs in the uteri close to the vagina are in an advanced stage of segmentation.

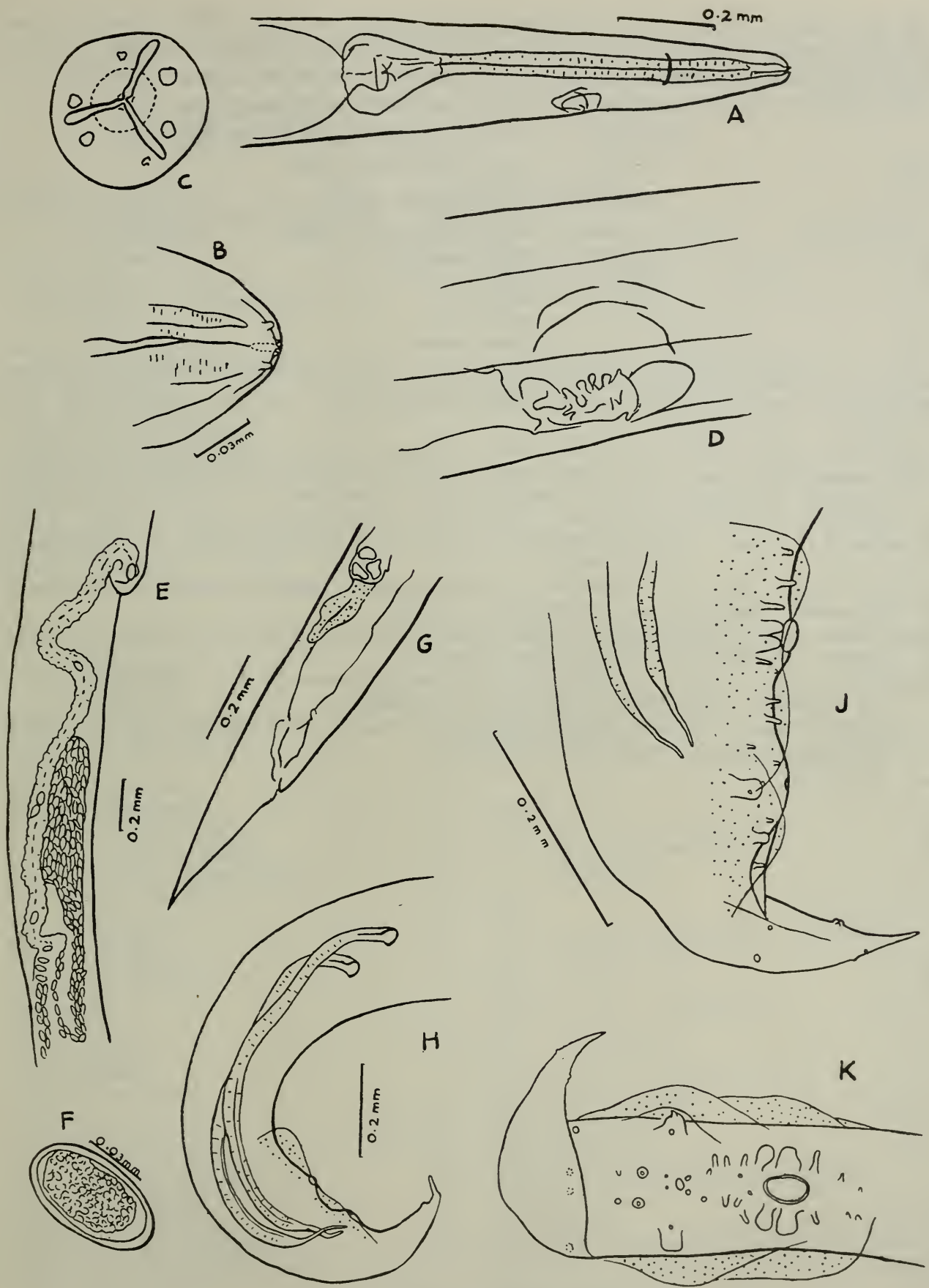
Discussion

Seven species have been recognised as belonging to the genus *Africana* Travassos, 1920. All the members of this genus seem to be closely allied and the differences in number and arrangement of the caudal papillae and the length of the spicules are considered as the main features of diagnostic value.

In *A. africana* (Genre, 1909) to which the worm described above is most closely allied, there are only nineteen caudal papillae and these are sessile and differently arranged. The spicules in *A. africana* are longer and in relation to the length of the entire worm they vary from 1/2.8 to 1/5 as compared with 1/6 to 1/7 in this species. In *A. africana* the pharynx is smaller and β is 3.8 to 4.3 in the male and 3 to 4.8 in the female as against 5.9 to 6.3 and 5.7 to 6.1 respectively in this species. Other points of difference are that in the species described here the ovaries are not confined to the anterior part of the body, the tail of the male does not end in a terminal spike and the eggs in the uteri are in an advanced stage of segmentation.

From the measurements quoted by Taylor (1924), it can be seen that the relative size of the subequal spicules in *A. acuticeps* (Geddoelst, 1916) and *A. brodeni* (Geddoelst, 1916) serve to differentiate them from this species. The whip-like appearance of the distal half of the spicules in *A. varani* Maplestone, 1931 and the eight longitudinal rows of body papillae in *A. howardi* Li, 1933 distinguish these species from the others. The number of caudal papillae, the length of the spicules and the position of the vulvar opening serve to differentiate *A. stylosterni* Sandground 1933. In *A. mabuyae* Chakravarty, 1944 the spicules are sickle-shaped and measure only 0.3 mm in length, the ratio of spicule to body length being 1:15.6.

The worm described above bears some resemblance to *Spinicauda longispiculata* Baylis, 1929 and *S. cophotis* Baylis, 1935 but, as Baylis (1936) pointed out, in *Spinicauda* Travassos, 1920 the lateral fields are conspicuous, the uterine branches are parallel, males are without caudal alae, the papillae are small and sessile and an accessory piece is present. These features are not seen in this species. In a few specimens, however, there was a suggestion of some chitinisation of the cloacal wall which could not be distinguished from the strong muscle strands associated with the cloaca and the pre-anal sucker. Digestion of the posterior end of



10. *Africana singaporensis* n. sp.

A, lateral view of anterior end of female; B, dorsal view of head; C, en-face view of head; D, excretory pore; E, lateral view showing vulva and vagina; F, eggs; G, lateral view of posterior end of female; H, lateral view of posterior end of male; J, lateral view of posterior end of male; K, ventral view of same.

the male worm with caustic soda as recommended by Clapham (1947) left no chitinized plates. Dr. H. A. Baylis, to whom the writer showed the camera lucida drawings included with this description, does not consider that this species could be referred to the genus *Spinicauda*.

- Family : *Heterakidae* Bailliet and Henry, 1914.
 Sub-family : *Heterakinae* Railliet and Henry, 1912.
 Genus : *Africana* Tracassos, 1920.
 Species : *A. singaporensis* n. sp.
 Host : *Bufo melanostictus* (Toad).
 Location : Large intestine.
 Locality : Singapore.

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OLD WORLD TROMBICULIDS

INDEXED UNDER PROVISIONAL GENERA AND SUBGENERA

The letters N, A, signify that Nymphs, Adults of the species are known.

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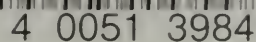
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